01

The Nature of Science and Innovation

A NERICA rice variety developed by the Africa Rice Center. © Gordon Conway

1. Why is science important?

Why is science important? Science underpins improvements in human welfare, through technologies which it develops for health, food production, engineering and communication. Science is also important in solving problems created by human activity, such as environmental degradation and climate change. Science allows us to move forward through incremental improvements in technology, adapted for particular needs and situations. But it also sometimes allows us to leap forward, through fundamental scientific discoveries that entirely change our sets of tools for human improvement, and create new platforms for technology, such as the genetic revolution and the consequent development of biotechnologies for improving health and agriculture.

The terms we use to describe science are explained in Box 1.1.

Box 1.1 What do we mean by science, technology and innovation?

Science is the process of generating knowledge based on evidence.[1] While it implicitly includes both natural sciences (biology, chemistry, physics, mathematics and related disciplines) and social sciences (economics, sociology, anthropology, politics, law), we will focus in this book largely on natural science disciplines.

Technology is the application of scientific knowledge, and frequently involves invention, i.e, the creation of a novel object, process or technique.

Innovation is the process by which inventions are produced, which may involve the bringing together of new ideas and technology, or finding novel applications of existing technologies. Generally, innovation means developing new ways of doing things in a place or by people where they have not been used before. Modern innovation is usually stimulated by **innovation systems and pathways**.

The phrase **'Science and Innovation'** in this book implicitly includes science, engineering, technology and the production systems which deliver them.

People who live in developed countries sometimes forget how scientific innovations have transformed their lives. They live much longer than their predecessors, they have access to a dependable supply and a great variety of foods and other goods, they can travel easily and quickly around the world and they have a myriad of electronic gadgets designed for work and pleasure. Much of this success is due to sound economic policies and to forms of governance that promote equality, justice and freedom of choice, but much is also due to advances in scientific innovation (Box 1.2).

How does scientific innovation work?

Scientific innovation involves the successful exploitation of new ideas to generate new techniques, products and processes. Traditionally, scientific innovation has been viewed as a process starting with curiosity-driven, basic research which generates new understanding. This then leads to translational research, which relates this fundamental understanding to systems we want to improve, and then to applied research, which produces the products which we can use. Private enterprise plays a key role in successful innovation – without business investment and marketing, inventions such as penicillin, computers and mobile phones would not exist today.

Box 1.2 Inventors past and present

The 20th century witnessed dramatic medical inventions – a vaccine against yellow fever, Fleming's discovery of penicillin, Salk's development of the oral polio vaccine, Barnard's first heart transplant. These and other discoveries have had widespread benefits unimaginable a century before and the pace of discovery shows no signs of abating. In 2005, the average UK life expectancy for men was 78 years, compared to 66 in 1950 and 48 in 1900.[2] The next wave of discoveries is likely to be treatments and cures for cancers and for the diseases of ageing, such as Alzheimer's.

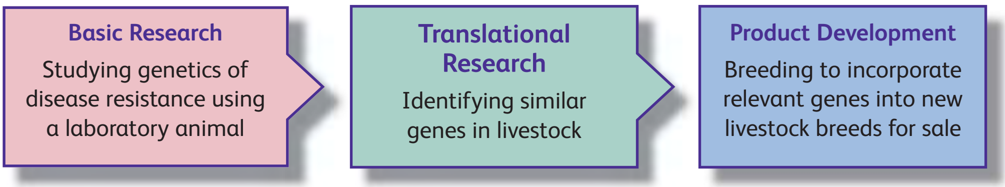
Figure 1.1 – Alexander Fleming in his laboratory in 1909 at St Mary's Hospital, London

But today it is inventions in electronics and communications that catch the imagination – Jobs' and Wozniak's development of the Apple computer, Berners-Lee's invention of the World Wide Web and its exploitation by Page and Brin in the form of Google, and by Omidyar's eBay.

Arguably the biggest recent impact has come from the mobile phone, but here it is difficult to identify a single inventor. The nature of invention has significantly changed: modern inventions are largely the result of team work.

As an example of innovation, consider how new knowledge of the genetics of disease resistance, gained from basic research on a laboratory animal, may lead to translational research on livestock to determine whether similar genes exist that convey useful resistance. If this research is successful, industry may use it to develop products, in this case using livestock breeding methods to incorporate genes conferring resistance into specific commercial breeds for sale to farmers (Figure 1.2).

Figure 1.2 – A linear process of scientific innovation



However, today we recognise that scientific innovation is not always a linear process, and that it often involves an interplay back-and-forth between basic, translational and applied research stages. It is possible, for example, for applied research to identify a need for more basic research in a new area. Going back to the example above, if new breeds exhibit only patchy resistance to the disease in question, farmers may choose not to buy the product. This may stimulate applied research into the causes of breakdown of resistance, which in turn may stimulate more basic research into resistance mechanisms, so as to generate new solutions.

This research interaction involves a diverse system of players and institutions that influence its progress and success. Together, these are often called a **science innovation system**. The players may come from companies, universities, government and civil society. Scientists play a key role, of course, but so do other stakeholders, such as policy makers, banks and investors. Involving policy makers allows for a conducive policy and regulatory environment for the development and use of new technologies, while banks and investors provide security and capital for product development. Figure 1.4 shows the framework for a basic science innovation system.

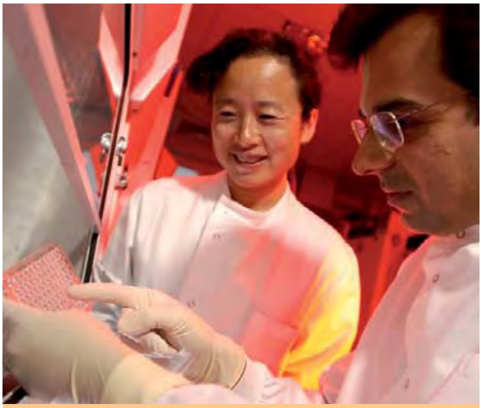
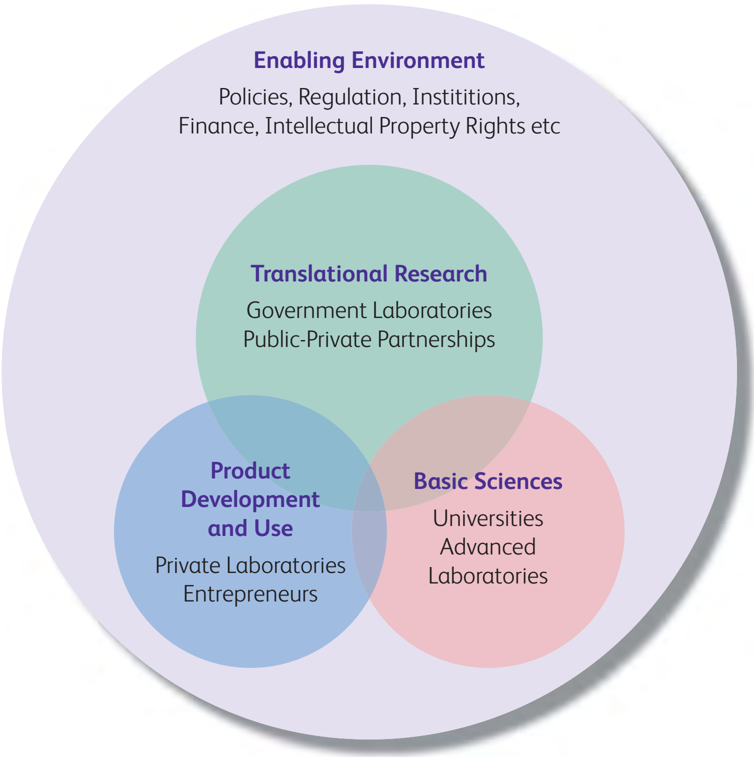


Figure 1.3 – Scientists from around the world collaborate to access best expertise

This concept of science innovation systems helps us to understand what is necessary for scientific progress to occur. Where science does not lead to innovation and new products, key players may be absent, or something may be blocking the two-way flow of ideas. In particular, it shows us that a range of elements must be in place and functioning before locally valuable technologies can result from scientific innovation.

Figure 1.4 – A science innovation system



A striking feature of science innovation systems today is that they are becoming increasingly international, with groups from different countries bringing specific expertise to the innovation process. Science no longer functions in isolation at a national level as it did with the large-scale emergence of nationally funded science during the 20th century, when it was seen as a way of ensuring national security and productivity. Scientists from around the world now collaborate with each other for a variety of reasons, but particularly to access the best expertise, resources and partnerships, and funding and institutions have adapted accordingly.[3] Importantly, certain scientists, institutes and countries participate much more actively in the system than others, thus influencing the direction and benefits of research and outputs.

2. The role of science in international development

The goal of international development is to reduce poverty and to help poor people build a better life for themselves. It recognises the profound inequities which exist between countries in the ability of their citizens to make lasting, positive changes in their health, environment, opportunities and security. Poverty is often described in terms of income per capita, with US $1 or $2 a day being used as thresholds below which people are considered to be impoverished. But poverty is as much about lack of opportunity for betterment as it is about income.

Poverty and inequity exists to some degree in all countries. International development programmes make a distinction between countries which are highly industrialised where citizens enjoy relatively high incomes – developed countries – and countries which are generally poorly or moderately industrialised where citizens generally have low incomes, with many living in poverty – developing countries. The terms ‘developed’ and ‘developing’ are not official designations but the United Nations (UN) and other bodies use them as convenient shorthand for classifying countries for investment (Box 1.3).

Science can make a valuable contribution to this goal. Scientific knowledge and technology can be applied to specific technical challenges like achieving the Millennium Development Goals (MDGs) – see Chapter 4. More generally, it can provide countries with the tools needed to reason, innovate and participate in the ever-expanding global science network, thus supporting national economic growth and sustainable development.

The contribution of science to development challenges

The challenges of improving the lives of those in developing countries are large and diverse, and will not be achievable without the contribution of scientific knowledge and innovative technologies. Many technologies have already made significant impacts:

- Vaccines have eradicated smallpox, are near to eradicating polio and have significantly reduced child and adult mortality;
- Oral rehydration therapy has saved the lives of millions of children with diarrhoea;
- Integrated Pest Management (IPM) has increased rice yields and reduced the use of pesticides;
- Breeding of high yielding varieties of wheat and rice has transformed food security in South Asia;
- Using a vaccine to eliminate rinderpest has removed a major risk to pastoralists and livestock farmers;

- Minimum tillage systems have reduced water loss and soil erosion;
- Treadle pumps have opened up opportunities for irrigation for small farmers;
- Water purification technologies have reduced the risk of epidemics after natural disasters;
- Mobile phones have improved access to markets and helped strengthen urban-rural family links.

Box 1.3 Designations of developed and developing countries[4]

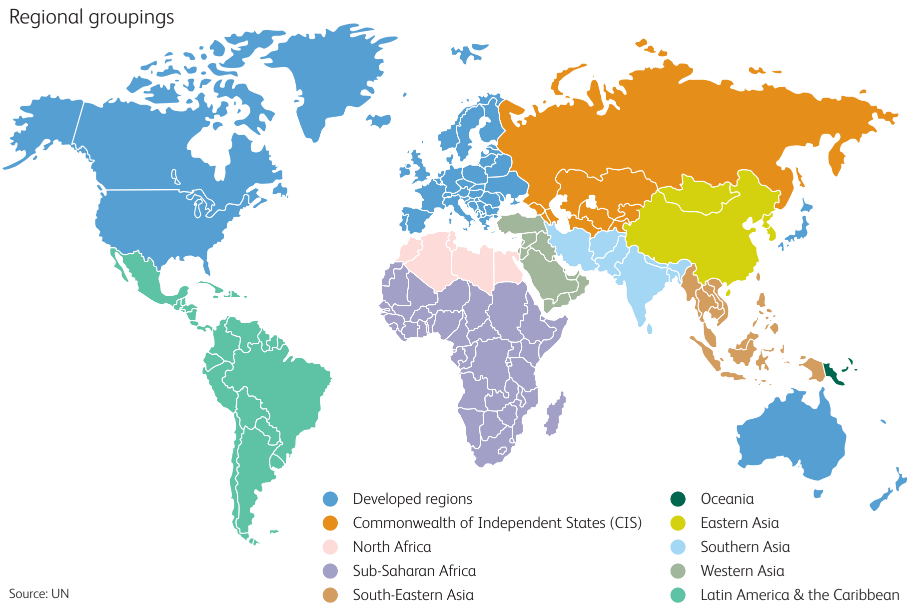


Figure 1.5 – UN regional country groupings

The developed regions comprise Europe (including the transition countries but not the CIS), Australia, Canada, Japan, New Zealand and the United States (US), shown in blue.

The CIS (Commonwealth of Independent States) which include the areas in Europe and Asia highlighted in orange above, are sometimes included in the developing regions.

However, in this report the developing regions are the rest of the world and can be subdivided into:

Middle income countries – such as Brazil, Vietnam and South Korea and including the '**Emerging Economies**' or BRICs (a term derived from the first letters of Brazil, Russia, India, China, but now used generally to describe countries with rapidly emerging industry and improving per capita wealth);

Low income countries – such as Kenya, Ghana and Honduras, and including the **least developed countries** such as Cambodia, Mali and Haiti;

Fragile States include those who are conflict ridden or recently emerging from conflict such as Afghanistan, Sierra Leone and Nepal.

Successes such as these have been achieved through years of experimentation by groups of scientists, often collaborating across countries and disciplines. It is therefore very important that scientific research and development, aimed at solving the problems facing the poor, is continued and given the funding and support it needs.

The benefits of scientific capacity

Developing countries face particular challenges in applying science and technology to their own development needs, because their science innovation systems are often weak or lack key elements, and their scientists have little access to global science networks. Strengthening national scientific capacity can bring a huge range of social and economic benefits to developing countries (Box 1.4).

Figure 1.6 – A nurse administering oral polio vaccine at a clinic in Freetown, Sierra Leone

Besides delivering new and valuable technologies, a strong national scientific capacity provides an evidence base to underpin sound political decisions and to challenge unsound ones. The central feature of the scientific revolution that began in Britain in the early 17th century was that hypotheses and assertions had to be scientifically tested. It was not good enough to base policy on theory, supposition or political ideology. This is as true and essential today as it was then.

Box 1.4 The importance of strengthening national scientific capacity

"Africa's ability to meet its human welfare needs, participate in the global economy and protect its environment will require considerable investment in science and innovation, in general, and engineering, in particular."[5]

Professor Calestous Juma, lead author of the Report of the Task Force on Science, Technology and Innovation of the UN Millennium Project

"There is one thing developing countries cannot do without: home-grown capacity for scientific research and technological know-how. Increasingly, a nation's wealth will depend on the knowledge it accrues and how it applies it, rather than the resources it controls. The "haves" and the "have-nots" will be synonymous with the "knows" and "know-nots."[6]

Ismail Serageldin, Director of the Library of Alexandria.

"In the world of the 21st century, critical issues related to science and technology confront every nation…Today, no nation that wants to shape informed policies and take effective action on such issues can be without its own independent capacity in science and technology."[7]

Kofi Annan, former Secretary-General of the UN.

Policies aimed at combating climate change or controlling disease pandemics are only going to be successful if they are based on convincing scientific evidence. Scientists and scientific institutions can play a particularly important role by providing the government with independent and authoritative expertise. In Africa, for example, the Network of African Science Academies (NASAC), has recently voiced its commitment to achieving this goal and working more closely with national policy makers.[8] Box 1.5 highlights work being done by the science academies in the US and UK to help African academies strengthen their capacity in this area.

Besides the contribution that strong science innovation systems make to delivering services to society, it also creates an ability at the national level to:

- Articulate and prioritise research needs;
- Absorb, learn from and put to use the technologies being developed in other countries;
- Develop unique technologies specifically suited for local problems;
- Add higher value to natural resource, agricultural and mineral exports;
- Improve learning and production in both small and large businesses and develop new enterprises;
- Establish effective domestic regulations to control the release of new technologies;
- Participate in the international scientific network, learning from, contributing to, and influencing the direction of research and technology development;
- Engage fully in international debate and negotiations on, for instance: climate change; intellectual property rights; biotechnology and nanotechnology;
- Benefit more from foreign direct investment; particularly in high technology, value-added sectors.

While each of these benefits is distinct, it is clear they are also linked and mutually-reinforcing. For example, well chosen research priorities influence the efficiency of the firms which are using outputs from national research. Improving national science capacity thus has a widespread and positive effect not only on national science innovation systems, but also on society as a whole.

Science capacity and economic growth

The changes which come from a stronger national scientific capacity have positive system-wide economic effects. As stated in a recent document produced by the New Economic Partnership for Economic Development (NEPAD):

> Nations' economic change and sustainable development are to a large measure accounted for by investments in science, technology and innovation. It is not the mere accumulation of physical capital and natural endowment that transform economies and stimulate human development but the ability of countries to produce, harness and wisely use scientific knowledge and related technological innovations. The economic history of the industrialised and newly industrializing countries vividly shows that economic improvement in these countries has been a result of the application of knowledge in productive activities. Indeed there is an explicit correlation between a country's scientific and technological capabilities and its economic performance and affluence.[9]

Box 1.5 Helping scientists provide the evidence

Figure 1.7 – A presenter at the 2008 ASADI conference in London

Begun in 2004 by the United States National Academy of Sciences, and funded by the Bill and Melinda Gates Foundation, the African Science Academy Development Initiative (ASADI) brings together the expertise of science academies in the US to work with national academies in Nigeria, South Africa and Uganda, chosen for their potential as well as the receptiveness of their governments. The initiative, which will run for ten years, focuses on building the capacity of the academies to work in a public service role, and act as liaisons between their country's scientists and the policy makers in the government.

Activities include:

- Training of academy staff in key skills areas, by linking counterparts in the US in different areas such as management, research and administration with those in Africa;
- In-depth policy studies by committees to explore important issues such as the link between AIDS and nutrition, or mosquito resistance to insecticides, in order to offer formal guidance to national decision makers;
- Organised gatherings of specialists for discussion on particular subjects of interest;
- Conferences, workshops and fora both nationally and between the various academies in Africa.

The initiative has also set up an electronic database of African scientists, which can be shared across countries to help academies and governments to recruit experts and find appropriate knowledge.[10,11]

Similarly, the Royal Society (UK), the Network of African Science Academies (NASAC) and Pfizer (US) have recently formed a partnership to build capacity in four national scientific academies in Ghana, Zambia, Tanzania and Ethiopia. The Royal Society Pfizer African Academies Programme aims to extend the broader skills base within these academies whilst building vital policy links and understanding between institutions, scientists and policy makers. The academies are at various stages of development and so the multi-year programme of mentoring, training and project support will be flexible to fit each academy's needs. The Royal Society and NASAC are working closely with each academy to maximise and tailor the impact of the programme to individual country contexts.[12]

At the most basic level, science can be linked to economic growth because science innovation contributes to productivity growth, which in turn drives capital accumulation, output growth and general economic growth.[13] For this to happen, there must be investment, public and private, in science innovation, as well as access to finance for those businesses that will produce and market the resulting new products and services. Purchased by individuals and businesses ranging from small farms to major industries, these products and services enable customers to increase productivity, so contributing to economic growth.

It is often difficult to establish or prove a direct link between these steps because of the complexity of the national economic systems into which new science and technology feeds.[14] Factors like effective accountable government, political stability and a commitment to appropriate economic policies also make important contributions to economic growth. Nonetheless, a number of nations have recently provided affirmation of the close relationship between investment in science and technology and economic growth.

Strong evidence for the contribution of science to growth comes from the newly industrialised countries of East Asia. Some of these countries have exhibited in recent decades the fastest rates of both economic growth and poverty reduction in the world. This has been associated with policy commitments to improve education in science and technology, to provide public sector funding and to encourage private sector development.

Investment in science has led to these countries becoming participants in global science systems. Today, we acknowledge that leading scientific innovation is not only coming from traditionally wealthy countries, but from a number of rapidly growing economies in the developing world, including China, India, Brazil and South Africa – 'the so-called emerging economies'.

The Chinese experience is particularly worth highlighting. China's recent growth in scientific research activity is impressive. Authorship of papers in international, peer-reviewed scientific journals by Chinese researchers has increased from 828 papers in 1990 to over 80,000 in 2007, second only now to the US.[15] China has made highly visible investments in engineering to develop the basic infrastructure for growth – especially transportation, irrigation, power generation and distribution. But what is particularly impressive in China is not just its phenomenal technological growth in the large eastern and south-eastern cities, but also the growth in the poorer areas to the north-west such as the Loess Plateau.

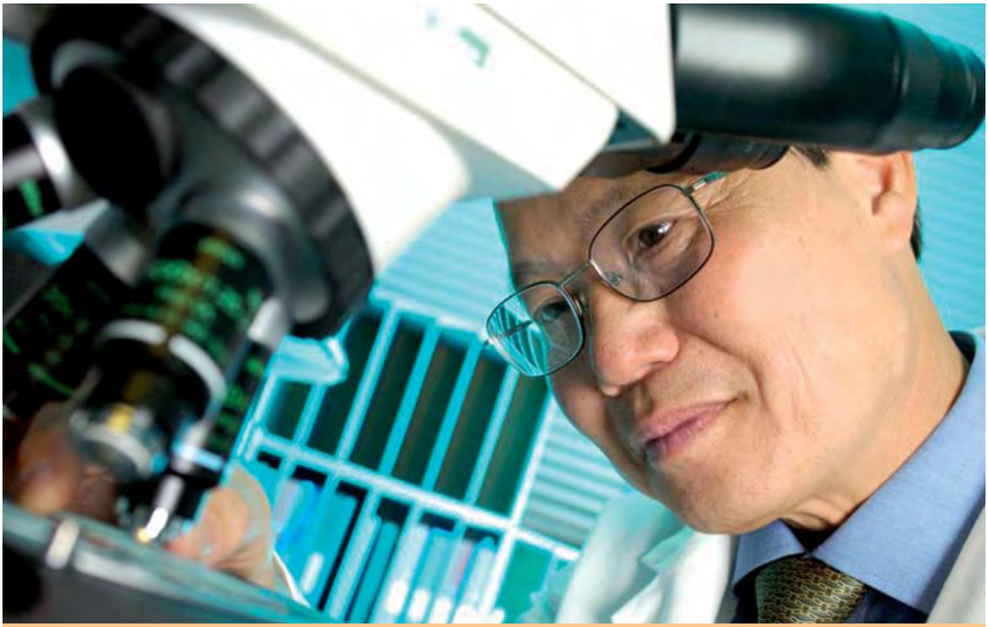


Figure 1.8 – China has seen an impressive growth in scientific activity

Poverty reduction in the Loess Plateau

In the early 1990s, the Loess Plateau was a vast area of extremely degraded and eroded land, and the hundreds of thousands of farming families living there worked hard for very little return. This, however, was completely turned around with an extensive and long-term World Bank project which ran from 1994 – 2005. World Bank experts collaborated with Chinese scientists and the local community to devise a watershed rehabilitation plan for the area which was highly successful.[16,17] Although funded by the Bank this would not have been possible were it not for the Chinese investment in science educatio allowed for the contribution of local scientists, as well as the investment in the necessary infrastructure and markets which allowed the local farmers to profit from their new agricultural surplus. Box 1.6 below describes some of the benefits of this project in more detail. The specific technologies used will be expanded upon in the next chapter.

Box 1.6 Science and innovation on the Loess Plateau watershed in China

The Loess Plateau covers a vast area of north-west China, some 640,000 square kilometres extending over six provinces and home to some 90 million people. It is distinguished primarily by its soil – a very fine, yet very deep, silt – blown from the west over millennia. The soil is easily worked and fertile yet readily prone to erosion. Following years of over-cultivation and misuse it was left highly degraded.

Before the start of the World Bank Watershed Rehabilitation project in 1994 the area had the highest erosion rate in the world, and 1.6 billion tonnes of sediment was being deposited annually into the Yellow River.

The project team began what became a nine year investment to work with local communities to rehabilitate the local ecosystem, reduce erosion and improve agricultural yields.

Figure 1.9 – A farmer on his degraded field on the Loess Plateau

Over the first two years experts from the World Bank, together with a large group of scientists from the Yang Ling Soil and Water Institute and the Chinese Academy of Sciences, worked to assess the situation and discuss options. The team included specialists in areas such as: agriculture; water resources management; forestry and environmental science. The scientists collaborated with social scientists from Beijing University, local government officials and the watershed committees they formed in over 2,000 villages.

The team used both micro and macro-level assessment techniques in order to get a complete and accurate picture of the situation. The results of participatory surveys and activities were compiled into a database, and combined with the scientists' observations and Geographic Information System (GIS) maps of the area. From this, a comprehensive package of interventions was developed with the farmers, which could be implemented in each community.[16]

The first goal was to restore the infiltration and retention of rainfall. With the support of the farmers, grazing was banned on all upper slopes to allow for the restoration of vegetation.

Figure 1.10 – Modern terraces on the Loess Plateau

A variety of technical interventions were then implemented which included improved modern terracing, sediment traps and dams and new tree transplantation techniques. The UK Department for International Development (DFID) became involved in 2003, adding support to the watershed management and monitoring process.

As a result, the landscape has been remarkably transformed. With the restoration of healthy water-cycling, arable land has been recreated and farmers are now getting higher yields of wheat and maize, and additional income from fruit harvesting. And, the changes have resulted in significant labour savings. Families are now able to pursue increased livestock production and other enterprises such as growing vegetables and flowers in greenhouses. This has all led to an increase in resources held and incomes earned by farmers, with an estimated 2.5 million people able to rise above the poverty level as an immediate result of the project, and even more long-term positive change expected.[18]

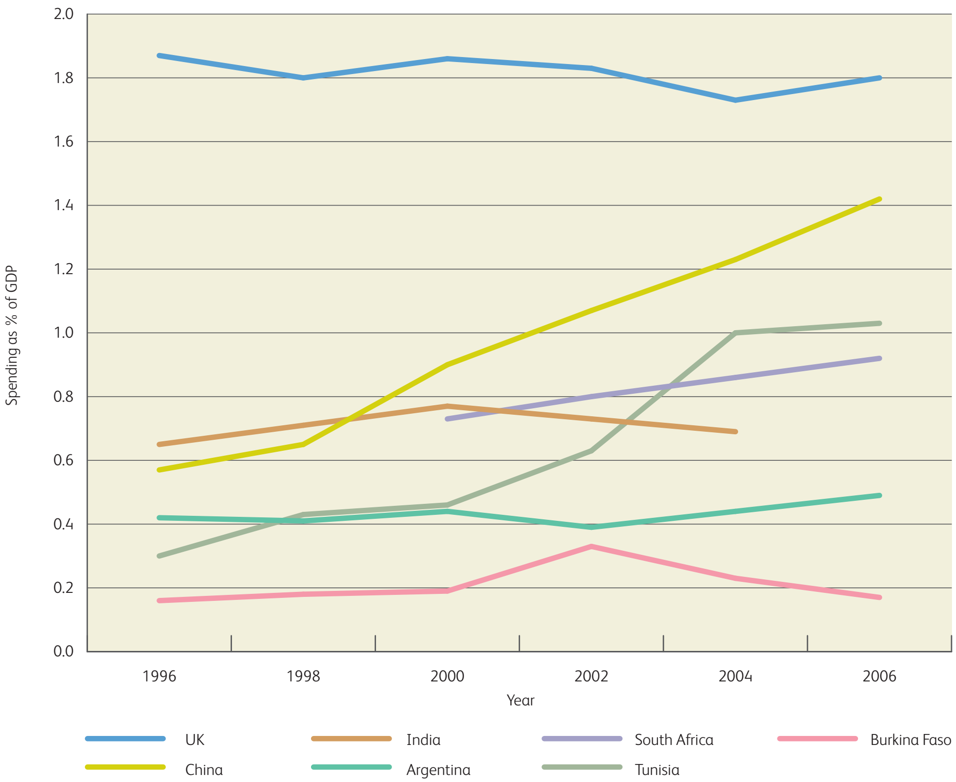
As this example demonstrates, investment in local scientific capacity can make possible effective collaboration aimed at solving local problems. And, at the household level the adoption and adaptation of technologies can increase incomes and productivity, both by increasing the productivity of existing employment, for example in agriculture and domestic labour, and by freeing up labour for additional income-generating employment. It can also help to upgrade skills, increasing the ability of the poor to either start up new income-generating activities, or enter new forms of employment. Initiatives like this have contributed to China's excellent record of poverty reduction: a remarkable 628 million people have crossed over the poverty line since 1981.[19]

3. The challenge ahead

Strengthening science capacity

While there is evidence that emerging economies have used science and technology to reduce poverty and achieve economic growth, the majority of poor countries have yet to go down this path. In fact, there is a huge range in scientific capacity and investment in countries throughout the world, with those countries who are most in need of its benefits usually the ones who are most lacking. Figure 1.11 for example, shows gross domestic expenditure on research and development (R&D) as a fraction of national Gross Domestic Product (GDP) for a number of countries over the last decade, revealing both substantial gaps between nations and impressive progress in some.

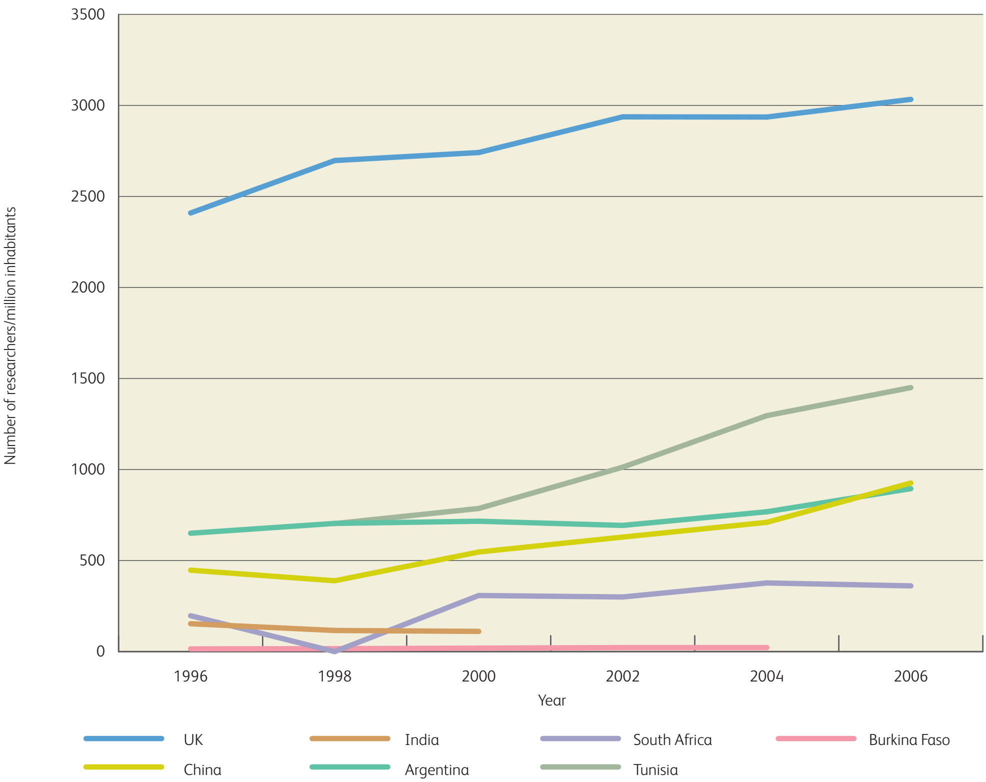
Figure 1.11 – R&D spending as a percent of GDP in various countries[20]



Of course, this investment, as discussed above, cannot always be directly correlated to economic success or poverty reduction. However, one can look at indicators such as the number of researchers, journal articles published or patents issued in a nation in order to get an idea of local scientific capacity and the likelihood of a society being able to benefit from it.

Figure 1.12 shows the number of scientific researchers per capita in the same set of countries as Figure 1.11. As one can see, investment by countries, like China, can translate into a growing number of researchers while, in a small country like Burkina Faso, there has been little investment and no increase in capacity.

Figure 1.12 – Number of scientific researchers in various countries[20]



Moving from a lower to a higher level of national scientific capacity has been described as a series of stages, with nations categorised by their level of capacity as below:[3,21]

- **Scientifically Lagging Countries**: Lack science, technology and innovation capacity almost entirely e.g. Indonesia, Burkina Faso, Syria;
- **Scientifically Developing Countries**: Have pockets of adequate science, technology and innovation capacity amidst general scarcity, e.g. Portugal, India, Iran, Pakistan, Uganda;
- **Scientifically Proficient Countries**: Display world class capacity in science, technology and innovation in some areas e.g. Singapore, Estonia, Korea, China;
- **Scientifically Advanced Countries**: With advanced science, technology and innovating capacity in all major areas; publish most of the articles in the internationally recognised journals and fund 80 % of the world's R&D. e.g. US, UK, Germany, Japan, Australia.

But how can countries best build up their scientific capacity? Studies of successful national scientific development suggest that countries need to first be willing to adopt and learn from other, more scientifically advanced countries. Once this investment is made, countries then invest in national capacity to manage scientific innovation and eventually to adapt technology to their own settings, to innovate and link to markets.[22-26] With a critical mass of national capacity in a particular area of science, these countries can then enter the global scientific network. As Caroline Wagner, Calestous Juma and others have pointed out, being a part of this global system can be extremely beneficial for a developing country, allowing it to quickly access scientific information and ideas and to further strengthen its national capacity in new areas.[3,24-28]

Governments must therefore aim to work investment in strengthening scientific capacity into national development plans. In doing so, a government may set priorities for investment based on its current strengths and local needs, and decide to outsource or collaborate on other important areas where it chooses not to invest directly. This allows a country to take advantage of the strengths of others and avoiding a duplication of effort. Wagner calls this strategy 'link and sink,' as each nation decides when to link with others, and where to 'sink' their resources.[3]

Figure 1.13 – Scientific capacity in countries such as Jamaica is still developing

Creating an enabling environment for science innovation

Investing in strengthening scientific capacity is only part of what is needed to produce successful innovation systems. Conditions must be created which make it profitable for the private sector to participate in innovation systems and to turn technology into valued products and services. This involves creating an effective enabling environment, including supportive regulatory frameworks, the protection of intellectual property rights, and banking and finance systems to facilitate and protect investments. Ultimately, it also requires the right infrastructure such as transport and energy supply systems, on which new products and services will depend.

Investment in scientific capacity building, therefore, must address both the supply and demand sides. An example of such investment is the recent Science, Technology and Innovation for Results (STIR) programme between the UK Department for International Development (DFID) and the Government of Rwanda. This £700,000 investment is contributing to the establishment of science capacity, including the establishment of a National Commission for Science, Technology and Innovation and a National Research Fund. The support helps build the legal and institutional frameworks that ensure that science and technology lead to practical, commercial innovations that benefit local industry.[29]

Signs of progress

Recently a number of developing country governments have made new commitments to strengthening science and technology capacity in order to address national development needs and to participate more effectively in the global economy and policy process.

Countries across Asia are making large-scale investments. Malaysia, for instance, is investing US $10m, and then $1.2m annually, in a new International Centre for South-South cooperation in Science, Technology and Innovation based in Kuala Lumpur.[30,31] In Latin America, countries like Brazil, Chile and Argentina are making substantial new investments in scientific research and development – in 2006, the region invested around $18 billion in R&D, a 60 % increase since 1997.[32] In January 2007, an African Union Summit endorsed a new focus on supporting national scientific research and development, including improving science education and revitalizing universities. Initiatives to strengthen science capacity and education have also been launched by the African Development Bank and several African nations. Nigeria, for instance, allocated $25 million in late 2006 to establish an African Institute of Science and Technology.[33]

This promising investment in strengthening national and regional scientific capacity will need to be sustained. It has been estimated that, even with political commitment and funding, it takes a scientifically "lagging" country between ten and 20 years to fulfil the criteria of a scientifically "developing" country.[3]

4. Scientific success in developing countries

In Section 2 of this chapter, we cited nine scientific advances which have contributed to international development over the past 50 years. In this last section, we look in detail at two quite recent examples of scientific innovation from Africa which illustrate some of the features of successful science for development, and particularly the value of global innovation systems.

One relates to improving the food supply for communities across Africa and the other to the reduction of the burden of disease.

New Rices for Africa (NERICAs)

Rice consumption is growing dramatically in West Africa, fuelled by population growth, rising incomes and a shift in consumer preferences, especially in urban areas. Local production, while increasing, is falling ever further behind demand. The region is now importing over half its requirements, some six million tonnes annually at a cost of over one billion dollars.[34]

The traditional African species of rice (*Oryza glaberrima*) has very low yields of about one tonne per hectare, compared with five tonnes or more for the Asian species (*Oryza sativa*). But, using tissue culture technology, Monty Jones, a Sierra Leone scientist working at the Africa Rice Center (WARDA), was able to cross the two species, producing hundreds of new varieties. At first the technique did not work well, but collaboration with Chinese scientists provided a new tissue culture method, involving the use of coconut oil, which proved highly successful.

The rice varieties produced in this manner, known as the New Rices for Africa (NERICAs), share many of the characteristics of their African ancestors. They grow well in drought-prone, upland conditions. Their early vigorous growth crowds out weeds. They are resistant to local pests and disease and tolerant of poor nutrient conditions and mineral toxicity. Yet as they mature, they take on some of the characteristics of their Asian ancestors, producing more erect leaves and full panicles of grain. And they are ready for harvesting in 90 to 100 days, that is 30 to 50 days earlier than current varieties. Under low inputs they yield up to four tonnes per hectare.[34]

NERICA rice has the potential to help meet the huge and growing demand for rice in Africa, and this can be achieved by increasing yields rather than through expansion onto ever more marginalised lands. There is also evidence that the need for less weed control and the shorter growing season is reducing the burden of child labour and improving school attendance in the areas it is being grown.[34]

Figure 1.14 – Panicles of NERICA rice

NERICA rice production has been steadily increasingly since the new seeds were first introduced in 1996, thanks largely to the pro-active approach taken by WARDA. Setting up partnerships across the region, WARDA has been able to work directly with farmers at all stages of the process, from varietal selection to seed dissemination. The process is not only participatory, ensuring that the priorities of a wide range of farmers are taken into account, but also efficient, speeding up the experimentation phase by an average of seven years, and streamlining seed dissemination by using the traditional farmer networks already in place. Farmers in west, central and eastern Africa are now growing some 200,000 ha of NERICAs.[34]

Figure 1.15 – Farmers in Benin happy with their harvest of NERICA rice

Insecticide treated mosquito nets

Another example of scientific innovation in Africa is the development of long lasting, insecticide-treated mosquito nets that kill mosquitoes, reducing the incidence of malaria. For several decades after the Second World War the preferred method for controlling the mosquitoes that transmit malaria was to spray the walls of dwellings, where mosquitoes rested, usually with the highly persistent insecticide DDT. However, the method required good logistics and infrastructure, and was never widely implemented in most African countries.

Moreover, DDT was found to be environmentally damaging and mosquitoes eventually became resistant, forcing a switch to less effective and more expensive insecticides.

A new approach to mosquito control in homes involved the use of mosquito nets treated with a pyrethroid insecticide. Early development of insecticide-treated nets (ITNs) was explored by researchers from the French *L'Institut de Recherche pour le Développement* (IRD, then ORSTOM) in 1983 in Burkina Faso, and later progressed in other parts of Africa by UK researchers from the London School of Hygiene and Tropical Medicine (LSHTM), the Medical Research Council (MRC), and others. Trials showed that treated nets give far better epidemiological protection than untreated nets, significantly reducing child mortality. Studies done by the MRC in the Gambia in 1986 and 1989, for example, confirmed that the use of ITNs resulted in a 63 % reduction in deaths of children under five.[35]

Encouraging initial results led to innovation in treatment of the nets, including 'dip-it-yourself' kits, more durable nets and finally nets where the fibres are coated with an insecticide coated resin and hence last for four to five years without re-dipping (known as long-lasting insecticide nets (LLINs). The insecticides used are photo-stable synthetic pyrethroids, fast acting yet safe to humans.

Since 1995, insecticide-treated nets have been used in the WHO's Global Malaria Programme with great success. But use varies from country to country, and there are still many African countries where less than 20 % of children are sleeping under a treated net. For example, in the Gambia, where the programme has had a longer and more aggressive promotion, 49 % of children under-five were estimated to be sleeping under an ITN in 2006, whereas in nearby Senegal, the figure is only 16 %, and in Nigeria only 1 %.[36]

The relatively high cost is a factor. A treated net can cost anywhere from £3 to £7, and promoters have realised that can be prohibitively high for many families. For this reason, a wide variety of distribution strategies are now being used, with a combination of free distribution, subsidies and 'social marketing' campaigns being taken up depending on the needs and preferences of the target population. For example, the 'Social Marketing of ITNs (SMARTNET)' programme in Tanzania, funded by DFID and the Royal Netherlands Embassy since 2002, is now providing LLINs free of charge to mothers of children under five, and for a reduced price of 500 Tanzanian shillings (about £0.20) for others.

Figure 1.16 – A baby sleeping under an Insecticide Treated Net

They are also using social marketing to lobby for transport subsidies, run press and media campaigns and organise displays at markets and in rural areas. Some three million nets a year are now being sold in Tanzania, double the annual sales at the beginning of the initiative.[37]

The Global Malaria Programme's goal is for 80 % of people in Africa, at risk of malaria, to be using ITNs by 2010,[35] which, while ambitious, is now being backed by more funding and political support than ever before.

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Figure 1.17 – Independent sellers of locally made ITNs in Lagos, Nigeria

Common elements of success

These two examples of successful science for development share several features common to the model of Global Innovation Systems described in Figure 1.4. Firstly, fundamental developments in science and technology triggered the innovations: tissue culture for the NERICAs and the development of pyrethroid insecticides for ITNs. Both of these inventions arose in the developed world and had been applied there for decades before they found these specific applications in Africa.

Both developments began in advanced research institutions, the Africa Rice Center (WARDA), and ORSTOM/LSHTM, respectively. While they were led and inspired by first class innovators, they were products of multidisciplinary teams linked into larger networks of scientists in both the developed and developing countries with whom they exchanged ideas and techniques. This international dimension was crucial. The Chinese helped with appropriate tissue culture for the NERICAs in West Africa, while the long-lasting mosquito nets made in Tanzania at the A to Z plastics factory, use resin from ExxonMobil in Saudi Arabia and Japanese insecticide technology from Sumitomo Chemicals.[38]

For both success stories, a range of donors were involved, including the World Bank, UNDP, the Gatsby Charitable Trust, Rockefeller Foundation, and the governments of Japan, Netherlands and the UK. The UK contribution, for example, was both specific and general: DFID supported the SMARTNET programme in Tanzania, and provided general support to WARDA laboratories and research through its contribution to the CGIAR[†].

These examples focus on technologies that were successfully adapted to new contexts, and so far this is how most successes have been achieved. As the global scientific environment changes, however, with new players emerging and many more slowly strengthening their capacity and joining the network, it is feasible that more innovative technologies will be developed with poor countries' needs in mind from the start.

† CGIAR is the Consultative Group on International Agricultural Research and is explained more fully in Chapters 2 and 3.

5. Conclusion – Improving science for development

The examples of NERICA rice and long-lasting insecticide-treated mosquito nets show how scientists in developed and developing countries can together address and solve problems, bringing us closer to the achievement of the Millennium Development Goals (MDGs). They illustrate the value of global science innovation systems and the collaboration they foster in improving science for development.

In conclusion, improving science for development will involve two main activities:

- First, the creation of effective global science innovation systems which engage scientists in developing and developed countries in addressing developing country science needs. These systems will be able to address major opportunities for achieving the MDGs as illustrated in Chapters 5 to 7 to follow.
- Second, strengthening the science and technology capacity of developing countries in key, relevant areas, including development of national institutions and innovation systems, enables them to address local scientific challenges with local knowledge and resources, and to participate more effectively and influentially in global science innovation systems.
- In the following two chapters we explore the sources of scientific innovation for development, and then discuss the kinds of partnerships in science innovation systems that may be involved. This is followed in the second part of this book with a detailed discussion of a set of MDGs – reducing hunger, improving health and conserving the environment, where we show how science innovation has the potential to contribute to these important challenges. In the third part we focus on the scientific and technological challenges in adapting to climate change.

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