03

Building Partnerships for Innovation

Villagers discussing a watershed plan with a state official in Haryana, India. © Gordon Conway

Producing successful science and technology for development involves creating science innovation systems in developing countries and building partnerships between developing and developed country scientists. In this way appropriate technologies can be generated that will address local challenges and opportunities while drawing on global sources of innovation.

The process requires that scientists interact with a wide range of partners. These range from local communities in developing countries with their traditional knowledge and understanding of the local context, to multinational corporations that have substantial investment in relevant R&D.

This chapter begins with a discussion on building national innovation systems and of the partnerships that are created between scientists in both national and international public research institutions. It then describes efforts to utilise indigenous knowledge and skills in the research and development process. Finally attention is drawn to the need to engage industry, especially in respect of innovative new platform technologies. In all these instances we illustrate the way in which national innovation processes are becoming more closely linked, in productive ways, with global systems.

1. Building national innovation systems

In Chapter 1 the benefits of building national science and technology capacity for developing countries were discussed. Now we describe the ways in which this can be achieved.

Innovation networks and clusters

National innovation systems are defined in many ways.[1] In the simplest terms they are *'networks of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.'*[2] The networks involve: universities and research institutes; small and large companies; financial and legal institutions; industrial associations; government ministries; NGOs of various kinds and individuals as both stakeholders and innovators in their own right.

It is generally agreed that such networks generate seven key functions:[3]

- Knowledge generation including R&D;
- Competence building;
- Financial support;
- Provision of regulatory frameworks and measures;
- Facilitation of information exchange;
- Stimulation of demand and creation of markets;
- Reduction of uncertainties and resolution of conflicts.

Experience suggests that successful innovation networks also depend on the creation of clusters of competing and complementary companies and research institutions. A key component is the existence of a vibrant small and medium-sized enterprise (SME) community with access to venture capital, either indigenous or foreign. Banks and other financial institutions are critical as are supportive economic incentives. Governments are also important, providing funding for technology incubators, export processing zones and production networks, as well as helping with skills training.[4]

Allied to SMEs is the need for a group of entrepreneurs. These may be scientists or engineers with strong experience of the practicalities of applying inventions to real life problems. But frequently, they are individuals with a business background, an appreciation of the market opportunities and a capacity to understand the essentials of the technologies on offer. In other words, they have a certain flair for spotting winners and seeing the process through from the embryonic stage to production and sale. These entrepreneurs can range from small farmers to senior scientists or engineers in companies or universities.

Often some of the most energetic national entrepreneurs are working abroad in industrialised countries. For example, India has made significant efforts to lure entrepreneurs back, at least on a part-time basis. The Rwandan diaspora have also developed contacts and skills, making them well placed to access global innovation systems and business networks. This has helped to generate income and bring capital funds into the country. Projects there have included the production and export of high-value coffee exports based on coffee-washing machines and the export of hand-woven baskets and bowls, which command high prices in up-market western retail outlets (Figure 3.1).[5,6]

Generally, the technologies are imported but there are significant local variations, which add greatly to the value of the processes. Two aspects are key to success. One is quality control, itself a technology, and the other is access to international markets.

(Left and centre) © Gordon Conway
(Right) © Joy Ndungutse – Gahaya Links

Figure 3.1 – A Rwandan basket making enterprise, Gahaya Links, started by sisters Janet Nkubana and Joy Ndungutse. Joy used the connections, market knowledge and capital she acquired while living in the US after moving there at the time of the 1994 genocide.

The national context

The goal of innovation policy is to embed education, training and R&D initiatives in a broader policy of competitiveness, linkages, cluster formation and entrepreneurship.[7,8] Innovation also depends on a wider supportive environment including customers who know what they want or can seize on the potential of new products and apply them to good purpose. In developing countries such customers are often government agencies. This requires a level of relatively sophisticated understanding, not only of the problems a country and its inhabitants are facing, but also of the potentials and pitfalls of new technologies and how they can be best adapted to local circumstances.

Innovation, in the developing country context, implies a strategic vision for national economic development and an integration of innovation networks within such a strategy. It is seen as a way to increase domestic productivity and international competitiveness. Also implied is the necessity to ‘catch-up’ with more technologically advanced countries. To begin with, innovation processes usually involve the acquisition and adaptation of existing technologies which have been successful elsewhere or, in the case of the new platform technologies, undergoing R&D elsewhere. In more sophisticated settings, particularly in the emerging economies, it may involve the development of quite new and ‘surprising’ technologies.

Experience suggests this is an evolutionary process that takes time and involves cumulative learning in which earlier, simpler capabilities and activities become more advanced. An important lesson to be learned is that development policies should adopt a calculated approach to technological catch-up. They need to choose key areas in which to build a critical mass of knowledge and skills, work along with the growth of business capabilities and domestic knowledge systems and keep in line with changes in the structure of the national economy.[9]

Capacity strengthening and education

Strengthening scientific capacity building is crucial and, among other tasks, this means investing in education at all levels. Recently emphasis has been placed on MDG targets of increasing enrolment in primary education. Many countries will achieve the 2015 target of MDG 2 to provide 100 % primary enrolment.[10] But this focus on primary education has created expectation and demand for secondary and tertiary education. Although less than 55 % of eligible children in developing countries currently enrol in secondary school, demand for higher education is growing rapidly. In Sub-Saharan Africa, for instance, enrolment in higher education has increased from 660,000 in 1985 to over 3.4 million in 2005.[11] Demand for places greatly exceeds supply, despite a rapid growth in provision, particularly by private universities. Many successful students are therefore entering universities that are under-staffed, under-resourced and poorly regulated.

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Figure 3.2 – Students at a village primary school in Mali

One recently launched African-led initiative has set out to address the problem. Organised by the African Development Bank the initiative aims to improve the training of highly skilled scientists and engineers in West Africa (Box 3.1).

The curriculum at universities in developing countries is often based on outdated models adopted from former colonial systems. There is a need to focus the curricula more on subjects which have local relevance and fit in with national capacity-building plans. Also programmes need to be revamped and be more creative in order to give talented students the tools they need to become entrepreneurs in their communities.[12]

Box 3.1 African Development Bank supports science and technology institutions[13,14]

The African Development Bank recently approved a US $17.6 million-equivalent grant beginning in 2010, to fund the 'Network of African Institutions of Science and Technology Project' in West Africa. The bank, recognising that *'higher education and skills development are central to economic growth and sustainable development,'* will be providing funds to improve education, training and networking opportunities for science and engineering students and professionals in the region.

The grant will start by targeting two key institutions, the African University of Science and Technology (AUST) based in Abuja, Nigeria, and the International Institute for Water and Environmental Engineering (2iE) in Ouagadougou in Burkina Faso. Through these two schools the project will host faculty exchanges and conferences as well as facilitate collaboration between the universities and local industry.

Concentrating efforts in this area should give a much-needed boost to the recruitment and training of skilled professionals in science and technology who can use their skills and knowledge to solve challenges specific to the West Africa region. To promote links with regional innovation, the bank will also train over 600 students from local petroleum companies who can bring their skills back into the private sector.

Under-resourced and poorly targeted higher education systems bring dissatisfaction amongst both students and trained scientists. For this reason, bright students and researchers leave to study and pursue careers in developed countries. This "brain drain" denies national science innovation systems some of their most skilled and motivated individuals. One way of addressing the "brain drain" is through new programmes, such as those coordinated by the Science Innovation Group, which supports MSc and PhD training for scientists and engineers in Africa. The group, through the Regional Initiative in Science and Education (RISE) programme, has set-up networks across a number of African universities, so that resources can be pooled in key subject areas, such as biochemistry and marine science. This support, along with links to experts abroad, helps encourage students to stay, and to prepare new, highly qualified teachers for the region.[15]

There is also enormous potential to make better use of the academic diaspora and their valuable education, experience and social networking resources in order to link developing countries into global research networks.[11,12,16]

2. Partnerships between scientists in public institutions

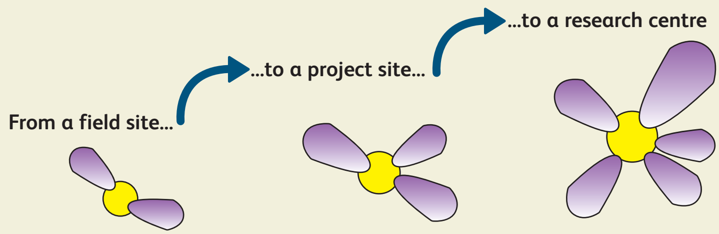
As described above, modern national innovation systems are highly developed partnerships involving scientists in a wide range of institutions. But to function effectively in today's world, developing country systems need to encourage their scientists to interact with scientists in other institutions and, in particular, with institutions in the advanced industrialised countries. Today such partnerships are most often formed between public sector institutions, such as universities and government research institutes.

These public sector partnerships will become increasingly important, as national innovation systems in developing countries build scientific capacity and become linked to global innovation systems. They should also become more equitable. Historically, where research has been funded by development donors, experts have commonly been drawn from developed country institutions and given management responsibility for the project funds. As a result, northern partners have usually dominated the research agenda. This means that, in the worst cases, they have approached science and technology challenges in developing countries with little appreciation of local context or existing knowledge or research, and left developing country partners with only token roles. Without their own resources or comparable specialised expertise, developing country partners have been compelled to let northern partners lead.

Developing equitable partnerships

The path to building national scientific capacity will often involve a shift from a dependence on short-term externally funded projects, to a position where core funding supports a scientific programme which can engage partners in a more equitable way. Figure 3.3 illustrates a concept developed by the Wellcome Trust for how this might happen for health research in Africa, where an initial research collaboration, wholly dependent on northern partners/funders can evolve into a local research centre.

Figure 3.3 – The development of locally-led health research centres[17]



What is the core?	Informal alliance of projects and trials at a site	Established infrastructure to projects and trials	Fully established entity that provides all science infrastructure
Core funding	Resources from projects fund the core	Small amount of core-funding and resources	Funding for core established and projects contribute to core
Portfolio	Small number of projects that drive the core	Small number of projects, but able to add different diseases or interventions	Different interventions or different diseases
Time focus	Short term	Mid term 3–5 years	Long term > 10 years
Infrastructure	Very basic and dependent on project funding	Established basics that survive individual trial and project	Full infrastructure maintained over time with projects paying share

The yellow circle indicates the core and the purple petals indicate the projects

Governments play a key role in this process by investing in infrastructure and core funding of scientific facilities. Recently, donors have supported the transition from project-dependent to institutional research in a number of ways. They have provided core research funding directly to national and regional scientific organisations in developing countries, the intention being that these institutions will set their own research priorities and provide funding competitively to local or international scientists in order to address these priorities. In African agricultural research, for instance, DFID, the EU and other donors provide funding to institutions such as the Forum for Agricultural Research for Africa (FARA) and regional research bodies like the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and West and Central African Council for Agricultural Research and Development (CORAF) which then develop and fund regional research initiatives.

Early career schemes can provide individual scientists with resources and opportunities to work internationally, while support to senior research leaders and their groups can help to develop career structures for young scientists. National recognition of the value of supporting and retaining scientists is critical. The establishment of scientific academies and national competitive grant schemes can also play a role in encouraging this political commitment. The Wellcome Trust has recently launched an African Institutions Initiative which gives five to ten years support to networked African universities and institutes, including funding for postdoctoral researchers to develop their careers, and for developing local postgraduate degree programmes.[17]

The Consultative Group on International Agricultural Research (CGIAR)

Over the years, a number of international research institutions have been set up to deal specifically with development research problems, and to bring together scientists and expertise from both the North and South for this purpose. The most unique and longstanding of these is the CGIAR.

The CGIAR was created in 1971 as an informal association of donors to provide financial support to four international agricultural research centres that the Ford and Rockefeller Foundations had established over the previous decade. They focused on rice, wheat and maize crops and had already produced dramatic results. Cereal yields, total cereal production and total food production in the developing countries more than doubled between 1960 and 1985. Over the same period their population grew by about 75%. As a result, the average daily calorie supply in the developing countries increased by a quarter, from under 2,000 calories per person in the early 1960s to about 2,500 in the mid-80s, of which 1,500 was provided by cereals.[18]

The so-called "Green Revolution" has proved most effective where there are well-resourced, national research and extension systems to distribute and support the new varieties, as well as good access to inputs, such as fertilisers and pesticides. This has been achieved in Asia, but only to a limited degree in Africa. Nonetheless, on a global scale, the uptake of crop varieties developed at the CGIAR Centres has been impressive: 65% of the global area under improved varieties of the ten most important food crops is planted with varieties derived from the CGIAR-funded research. Without the CGIAR contribution, it is estimated that world food production today would be 4-5% lower and in developing countries 7-8%.[19]

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Figure 3.4 – IRRI researchers examine a wild rice variety in the Philippines

In the 1980s and 1990s, new Centres joined the CGIAR, enjoying the benefits of core research funding provided by the donor group (Figure 3.5). These extended the research activity of the CGIAR beyond food crops to include: livestock; living aquatic resources; forestry and agroforestry; water resources; agriculture capacity building and policy. The focus of the CGIAR on crop genetic improvement has also been expanded to include natural resource management and policy research, which has emerged as important to realizing the benefits of crop improvement and sustainable agricultural growth.

Figure 3.5 – The world-wide spread of the CGIAR centres†

CGIAR members   CGIAR supported centres   CGIAR regional offices

Placement markers are approximate and indicate city locations, not worldwide offices

Since their establishment in the 1960s up until 2001, the Centres, supported by the CGIAR, have spent about US$7 billion (in 1990 US$). Cost benefit studies indicate that, by conservative criterian, overall economic benefits attributable to CGIAR research have been at least double the cost of research costs. This only includes a very limited set of directly attributable impacts. If expanded to include all of the known 'significantly demonstrated' and 'plausible' impacts, the benefits through to 2001 are estimated to be about nine times greater than research costs. If this is then extrapolated through to 2011, it is as much as 17 times greater.[20,21]

Fundamental to the success of the CGIAR centres has been the development of partnerships with national scientific centres. Box 3.2 describes the way in which the International Maize and Wheat Improvement Center (CIMMYT) has partnered with the Kenya Agricultural Research Institute (KARI).

The CGIAR has not been without its challenges. The critical core funding from donors has declined over time and Centres have operated independently, missing opportunities for synergy.

† The CGIAR centres include: Africa Rice Center (WARDA); Bioversity International, CIAT – Centro Internacional de Agricultura Tropical; CIFOR – Center for International Forestry Research; CIMMYT – Centro Internacional de Mejoramiento de Maiz y Trigo; CIP – Centro Internacional de la Papa; ICARDA – International Center for Agricultural Research in the Dry Areas; ICRISAT – International Crops Research Institute for the Semi-Arid Tropics; IFPRI – International Food Policy Research Institute; IITA – International Institute of Tropical Agriculture; ILRI – International Livestock Research Institute; IRRI – International Rice Research Institute; IWMI – International Water Management Institute; World Agroforestry Centre (ICRAF); WorldFish Center.

Box 3.2 A complementary partnership between CIMMYT and KARI[22-24]

CIMMYT was one of the first CGIAR centres. Founded in 1966 in Mexico, it is a large-scale international research and training consortium with offices in Asia, Africa and Latin America and over 600 staff. CIMMYT has built-up considerable expertise on maize crops. Maize varieties, developed by CIMMYT and its partners, are now planted on nearly half of the area sown to improved varieties in non-temperate areas of the developing world. CIMMYT's gene bank holds 25,000 unique collections of native maize races.

To effectively bring this high-level knowledge to the national and local levels in Kenya, CIMMYT has been working with KARI. Established in 1979 by the Kenyan government, KARI brings together national research and dissemination efforts in food crops, livestock management, land and water use.

Since the early 1990s, CIMMYT has worked with KARI on various projects, including developing maize varieties that are resistant to streak virus, stem borers, the weed Striga and drought. For example, to help tackle the destruction caused by stem borers, CIMMYT researchers found strains resistant to the borer in the centre's gene bank, in maize seed originally from the Caribbean.

KARI provides the crucial next steps in the innovation chain. Working with Kenyan farmers, the scientists used conventional plant breeding techniques to cross the introduced varieties with maize varieties already adapted to the conditions found in eastern Africa, selecting for traits which the farmers valued. KARI then facilitated the testing of the new strains through the Kenya Plant Health Inspectorate Services and helped to create a dissemination process involving local seed distributors and extension agents. When this is fully complete the new varieties will be available not only to farmers in Kenya, but will be given back to CIMMYT to be used in future research.

More importantly, investment in the CGIAR Centres has not been matched by investment in national research capacity in many regions, particularly Africa. This has led in some cases to research resources flowing disproportionately to CGIAR Centres, as well as a brain drain from national programmes into better supported Centre jobs, undermining the partnerships between Centres and national scientific research systems.

All of these problems are the target of an ambitious plan, launched in 2008, to reform the CGIAR system, bringing Centres and partner institutions together around a single strategic results framework with more sustainable funding.[25]

3. Participatory research and innovation

In addition to the conventional partnerships between scientists in Northern and Southern public sector institutions, science innovation systems for development are now building quite different kinds of research partnerships. Here we explore one – participatory research which involves local communities as research partners.

It is hard today to conceive that one might develop appropriate technologies in developing countries without the participation of the people they are meant to benefit. And yet the concept of the participation of users and beneficiaries in the development of new technologies is relatively young. This is sometimes true even in developed countries. However, developed countries have strong, well resourced innovation systems in which potential users participate and articulate demand which guides basic and translational research. In developing countries technology users, and in particular the poor, are rarely included in innovation systems.

The scientific community in both the developed and developing world is now recognizing the value of extending partnerships in research beyond scientists to user communities, so ensuring technologies are appropriate and, therefore, adopted. This has often meant that user communities, which were originally engaged only at the point of testing new technologies and their local adaptation, are now becoming engaged much earlier in the process. They help to identify objectives for research and development and participate pro-actively in the research.

The techniques of participation

As a result of a long-term accumulation of work undertaken in the 1970s and 80s, we now have effective techniques to make local participation in research and project design a reality. Under the headings of Participatory Rural Appraisal (PRA) and Participatory Learning and Action (PLA) there is a formidable array of methods which allow communities to analyse their own situations and, importantly, to engage in productive dialogue with research scientists and extension workers (Box 3.3).[26-29]

Box 3.3 Participatory learning, analysis and action

Participatory Rural Appraisal (PRA) methods, which help farmers to collect, analyse and present their own information, began in the late 1980s. They developed out of earlier participatory approaches of combining semi-structured interviewing with diagram making, drawn from the classical tools of ecology. The term Participatory Learning and Action (PLA) followed on from the success of PRA, as practitioners realised that the tools could be applied to many challenges beyond the rural and agricultural.

These approaches have enabled local people to take the lead, producing their own diagrams, undertaking their own analyses, developing solutions to problems and providing recommendations for change and innovation. For example, maps are readily created by providing villagers with chalk and coloured powder and giving them no further

Figure 3.6 – Farmer constructing a calendar to describe the seasonal sequences in the farming year. The stones mark the months of the year and the seeds indicate the amount of activity, such as days of weeding

instruction other than the request to produce a map of the village, a watershed or a farm. People who are illiterate and barely numerate can construct seasonal calendars using pebbles or seeds.

Such diagrams not only reveal existing patterns but highlight problems and opportunities and are seized on by people to make their needs felt.

Participatory methods have now spread to most countries of the developing world, and have been adopted by government agencies, research centres and university workers as well as by NGOs. In many ways it has been a revolution, a set of methodologies, an attitude and a way of working, which has finally challenged the traditional top-down process that has characterised so much development work. In every exercise the traditional position of rural people being passive recipients of knowledge and instruction has been replaced by the creation of productive dialogues.

In one of the villages participating in the DFID funded Western Orissa Rural Livelihoods Programme in India, for example, the villagers produced a portfolio of maps and analyses of their local area. This included maps of landforms, bodies of water, holdings and crops, an analysis of households, including their income status, and a list of project priorities that they formulated and requested funding for.[30,31] In some ways this is the ultimate example of demand-led development.

Institutionalized participatory research

While the benefits of using participatory methods for village or regional-level data gathering, discovery or analysis have become increasingly clear, involving local communities in scientific research on a wider scale is more challenging. Research scientists, policy makers and product developers are frequently far removed in location, language, priorities and methods, from the community members who are meant to benefit from the process. However, a number of groups have indeed had success, with positive results.

Developing new crop varieties and production methods

One area where a participatory approach has been widely adopted is in development of new crop varieties, for very specific reasons. The first Green Revolution targeted some of the best favoured lands in the developing countries. The land holdings were reasonably large, flat and well watered. In these situations it was relatively easy for agricultural extension workers to promote a simple, uniform package of seeds, fertilisers and pesticides, a model for crop production typical of that in industrialised countries.

The targets now are very different – millions of small farmers inhabiting an extraordinary diversity of land, soil and climatic types – and thus a new ‘Doubly Green Revolution’† is required which is both productive and environmentally sensitive. There are no simple technology packages or messages. Indeed every farm requires its own special set of recommendations. In this context, the traditional top-down approach will not work and the only way forward is to involve farmers in the analysis, design and experimentation processes.

© Ray Witlin – UN Photo

Figure 3.7 – Small farmers face a wide range of different situations

† A Doubly Green Revolution is one which *‘repeats the success of the Green Revolution on a global scale in many diverse localities and is equitable, sustainable and environmentally friendly.’*

It is common now for breeders to involve farmers in the selection of new varieties, Participatory Varietal Selection (PVS), and in the breeding process itself, Participatory Plant Breeding (PPB) (Box 3.4). In PVS researchers choose a set of varieties which they think farmers may prefer to the one currently being grown. Farmers then test these side-by-side in community fields and individually in their own fields (see also Box 9.14). They can then select varieties which meet their priorities – often bringing up valued traits which the researchers had not thought of, such as ease of threshing or aroma.[32]

Box 3.4 Farmers call the crosses[32]

In PPB scientists start with a set of varieties which are not completely desirable in themselves, but which contain traits selected for by farmers. They then cross these varieties to produce a diverse segregating population. Selections are then made from this population grown under farm management by researchers and farmers. Subsequent generations are grown by farmers, with the most desirable varieties being selected from each cycle.[33]

Figure 3.8 – Farmers selecting among the crosses

This process has been improved with the aid of molecular biology and marker-aided selection (MAS). The characteristics being sought by farmers are often difficult for them to detect or select for when testing, such as a good rooting system. Researchers can also use genetic markers to help prioritise farmers' choices in the breeding programme.

For example, rice breeders from the DFID Plant Sciences Research Programme in eastern India started with a very broad cross between Kalinga III – a popular variety but prone to breakage of stems (causing "lodging" and loss of yield) and to early season drought – and IR64, a high-yielding variety bred by IRRI with good disease, pest and lodging resistance. The farmers selected 20 varieties from this cross and grew them in diverse ecological settings in India and Nepal.

The breeders then tested 28 markers on the genome and found that the farmers were selecting for specific genomic regions from Kalinga III for the uplands, and from IR64 for the lowlands. With this information, new varieties can be designed which contain the desired 'bits' of the genome for each different growing condition.

The process has continued and just recently an upland rice variety 'Birsa Vikas Dhan III' (Pyramid 84) was released in Jharkhand state, India, that was developed through the combined use of PPB as well as MAS.[34,35]

Participatory research may extend beyond the breeding of varieties, to the development of new production methods. An example of this is work done in Syria to improve olive tree cultivation methods, described in Box 3.5.

Box 3.5 Participatory olive tree cultivation research in Syria[36-38]

Beginning in the 1990s, farmers in the arid Khanasser Valley in northern Syria started planting olive trees to supplement their incomes – hoping to turn marginal lands into profitable resources. The number of olive trees grew by 50 % in a decade, up to around 11,000 by 2003, with an average household cultivating around 100-150 trees. The farmers, however, did not have a long history of olive cultivation to draw knowledge from, and with little water available for irrigation and poor soil quality, yields were far from ideal.

The International Center for Agricultural Research in the Dry Areas (ICARDA) came to the area in 2003 to work with the farmers. Rather than attempt to find solutions on their own, researchers formed a committee of farmers and local extension workers to begin a process of participatory research, evaluation and innovation. Meetings were held to identify the most pressing problems the farmers were facing, which included limited water supply and how to cope with droughts.

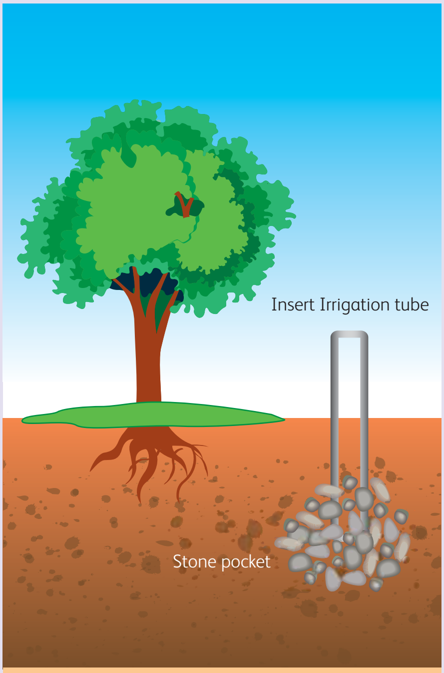


Figure 3.9 – 'Insert Irrigation' technology brought from Tunisia to Syria[36]

Experiments were designed and implemented by the farmers and scientists together, with regular meetings held to evaluate progress. At the end of the trial period a number of new technologies were identified, and are now being adopted by some of the farmers in the area. These include:

- *Water Harvesting* – the construction of V or fishbone-shaped, stony-earth bunds around each of the trees to create micro-catchments which can contain water around the tree and control soil erosion.
- *Stone Mulching* – covering the soil around the tree trunk with stones to reduce evaporation losses from the soil surface. Project experiments showed that basalt stone worked better than the chalky limestone the farmers had previously been using.
- *Sub-surface Insert Irrigation* – One of the farmers in the valley suggested an irrigation method he had seen being used in Tunisia. A stone pocket or gravel layer is constructed underground around the root zone of each tree. A PVC tube is then inserted vertically into the pocket and water is applied through the tube, so that it goes directly to the deeper roots.

So far these innovations are working reasonably well. But they do have problems, for example increased weed growth in the water harvesting basins. However, such issues can now be addressed by the group, leading to further research and collaboration, rather than ending in a failed research and extension project.

These examples illustrate the challenges of the new Doubly Green Revolution. Instead of starting with the biological problems inherent in producing new high yielding food crops or improved farming practices and then determining how the benefits can reach the poor, this new Doubly Green Revolution has to reverse the chain of logic.[18] It has to start with the socio-economic demands of poor households and then seek to identify the appropriate research priorities.

Technologies for health and the environment

It is not a coincidence that these examples of participation relate to rural land use and agriculture. Rural environments and local, traditional practices are highly variable, and the application of packaged, conventional technologies often fail to be universally appropriate over such a range of conditions. Thus, local participation and experimentation are particularly important in ensuring that technologies are well adapted to local environments and land management practices, and therefore of value to the poor.

However, local participation can also be important in the uptake of other, less location-sensitive technologies, such as those associated with engineering or healthcare, particularly where human behaviour is involved, as will be discussed in Chapter 6. Technologies for sanitation are one example where the input of local people is highly important in determining acceptance and use. Box 3.6 below considers one initiative that aims to involve communities in the design, construction and continued improvement of household latrines.

Box 3.6 Community-Led Total Sanitation[39-41]

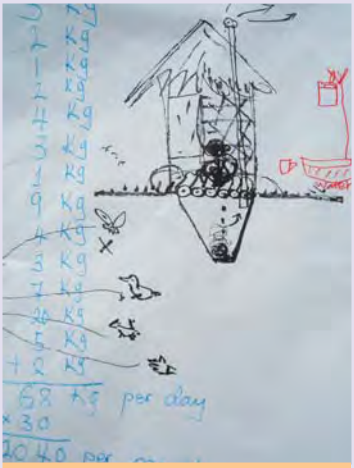


Figure 3.10 – A proposed latrine design drawn by a group during CLTS activities in Zambia

Community-Led Total Sanitation (CLTS) is an approach that was pioneered in Bangladesh in 2000 by an independent consultant from India, Kamal Kar, who was working with WaterAid, Bangladesh and its local partner Village Education Resource Center (VERC). He realised that the programme being used at the time, which concentrated on the construction of highly subsidised household toilets, was not working. While the number of toilets was increasing, people continued to defecate in the open, and so the desired health benefits were not being realised.

The basic principle of CLTS is "the empowerment of local communities to do their own analysis and take their own action to become open defecation free."[39] A facilitator, who can be either a trained local person or an NGO or local government worker, helps the community to analyse their sanitation practices, through a variety of activities, many based on PRA techniques. They include mapping the community and its defecation areas, 'transect walks' to see where people defecate, calculating the amount of faeces produced each year, as well as the medical expenses for treatment of diarrhoeal diseases. Other exercises illustrate the faecal-oral contamination route. Feelings of shame and disgust often arise and the realisation that

© Kamal Kar

Figure 3.11 – A man in West Bengal showing the latrine he built after CLTS activities

everyone is literally ‘eating each others’ shit (the crude word is always used), usually triggers the desire for change. This is called the ignition moment and spurs discussion as to what can be done.

The facilitator is not there to teach or tell the community what to do. Instead he or she allows the community to discuss its options and often natural leaders emerge and take charge of the process. If the community insists that building latrines is too expensive, the facilitator, upon request, may share low cost latrine designs that other poor communities have developed. The community often decides to take immediate collective action to end open defecation and become Open Defecation Free (ODF). Communities across Bangladesh, and in more than 20 countries in Asia, Africa, Latin America and elsewhere, have designed and constructed thousands of pit latrines as a result of this initiative.

Designs range from close replications of others that have been seen nearby, to creative and original ideas based on available materials and space – and the desires of the household. The big change here from other sanitation programmes is that the construction is motivated by real demand from community members and is therefore more sustainable. As households discover the benefits of sanitation, they may decide to move up the sanitation ‘ladder’, improving on the initial simple pit latrines over time. Plan International, UNICEF, WaterAid and the Water and Sanitation Programme (WSP) of the World Bank have been leaders in spreading CLTS and many NGOs and governments are now using this approach.

4. Engaging with industry in research for development

In the past, the development of most new technology for the poor in developing countries was supported from public funds. For example, the semi-dwarf wheat and rice varieties that were at the core of the Green Revolution's success were produced by the publicly funded CGIAR centres such as the International Rice Research Institute (IRRI) and CIMMYT.

International spending on research as a whole however, has come predominately from the private sector and has been directed at profitable markets in developed countries. Consequently, the range of products for use in developing countries remains small with major constraints on their access by poor people.

The cause of the failure of the market in developing countries is the actual or perceived lack of profitability of producing goods for poor people. Although the size of the market, in terms of need, is enormous, it is small in terms of market demand. For example, the average national expenditure on health care in most of the countries of Sub-Saharan Africa is less than US$10 per person per year. By contrast, per capita expenditure in developed countries is in the thousands of US dollars.[42]

Box 3.7 Quotation from Jean-Pierre Garnier, former CEO of GlaxoSmithKline

"The pharmaceutical industry must continue to invest in innovation to seek better solutions for tackling these killers. However, there is a dilemma. While we feel a moral duty and a fundamental desire to conduct research and development into vaccines and medicines for the diseases that blight the developing world, the harsh truth is that there is limited profit to be made from them. Yet to survive pharmaceutical companies must be profitable to deliver shareholder value."[43]

The market in the developed countries, targeted on the diseases of the rich – cancers, heart and circulatory failure and the diseases of ageing – is very profitable, giving a high return on the research and development investment. Development costs for vaccines, however, range from US$250 million up to US$1 billion[44], largely due to the costs involved in undertaking clinical trials. The pay-off is relatively low compared to more profitable pharmaceuticals. The annual global market for vaccines was US$20 billion in 2008, compared to US$770 billion for pharmaceuticals.[45,46]

The economics of commercial drug development do not favour products for the poor, where inexpensive vaccines and medicines are needed for diseases such as HIV/AIDS, TB and malaria. Until recently, these three diseases alone were estimated to account for 90 % of the global disease burden but only attract 10 % of international research – the so-called 90:10 gap. They carry – with a wide range of other largely tropical diseases – the title of "neglected diseases" which have a disproportionate impact in developing countries. Not surprisingly there is a lack of effective products and no commercial market to attract R&D from the private sector. However, with growing attention being paid to these diseases, largely through the public-private partnerships discussed below, this ratio is gradually changing.[47]

In 2007, about US$2.5 billion was spent on R&D in the area of neglected diseases, almost 80 % of it directed to the three diseases just mentioned. Other groups of important neglected diseases, like diarrhoeal diseases, received less than 5 % of the total funding. Most of the funding for this research – about 70 % – comes from public sector institutions, with philanthropic organisations contributing about 21 % and the private sector only about 9 %.[48]

In agriculture, the situation is similar. There is considerable demand in the developed countries for improved seed for highly subsidised farms. While there are important public sector crop improvement programmes, much of the research funding for this is provided by the private sector and goes towards key food crops like maize and wheat. But in developing countries the private sector is largely concentrating on cash crops such as cotton, where farmers can afford to buy seed, rather than staple crops. Developing countries share a number of staple crops with developed countries, but the varieties grown are different. Many staple crops for the poor are largely tropical, including rice, sorghum, millet and a range of root crops and pulses. These crops of the developing world have been relatively neglected with respect to modern plant breeding. Public sector funding for crop breeding in the developing world has been limited and the private sector even more so. These crops do not offer markets which are attractive to the kind of private sector agricultural R&D investment enjoyed in developed countries.

For example, the combined annual funding of the CGIAR consortium, which comes from governments and philanthropical organisations, is about US$500 million.[49] By contrast, the fifteen leading agricultural research multinationals – which include Bayer, Dow Agro, DuPont, Monsanto and Syngenta – spent about US$5 billion on agricultural research in 2008, but this is largely to produce technologies for subsidised, commercial agricultural producers in developed countries.[50]

Public Private Partnerships (PPPs)

In some situations, public sector research generates important technologies for the poor which would not otherwise exist. But, it is also critical to attracting private sector investment in the development and marketing of new technologies of all kinds. Such investment may come from local small and medium-sized enterprises or from multinational corporations. Both can benefit from the capacity of public sector research to:

- Provide access to up-to-date information on new technologies;
- Leverage private sector investment by taking technologies “near market”;
- “Backstop” and “trouble-shoot” the commercial launch of new technologies and their uptake;
- Create an appropriate enabling and regulatory environment.

One particularly effective approach to accessing private sector research in support of development goals is through the creation of PPPs. These may invovle a wide range of participants: public sector; government or university research institutions; private industry; NGOs and Foundations. But the principle underlying PPPs is that they bring together quite different players to share resources and complementary skills. The key benefits of PPPs include:

- Combining private sector skills in specification, innovation and product development with public sector knowledge of the social, political and economic dimensions of the problem at hand;
- Bringing private sector infrastructure and manpower into partnership with public sector institutions that have insufficient capacity to develop products efficiently;
- Permitting access to proprietary know-how and technology to address problems of the poor.

Health PPPs

Significant progress has been made by PPPs that address neglected diseases of humans and animals. Box 3.8 illustrates a number of these. Some disease-related PPPs are aimed at the development of a single drug or vaccine, or a range of products against a single disease. Others are directed at improving access to treatment. Still others provide a global coordination mechanism for funding research on different targets, e.g. the Global Fund to Fight Aids, Tuberculosis and Malaria. Such funds "leverage" private sector funding by guaranteeing to purchase the products of research, up to a certain value, if they meet agreed standards.[51]

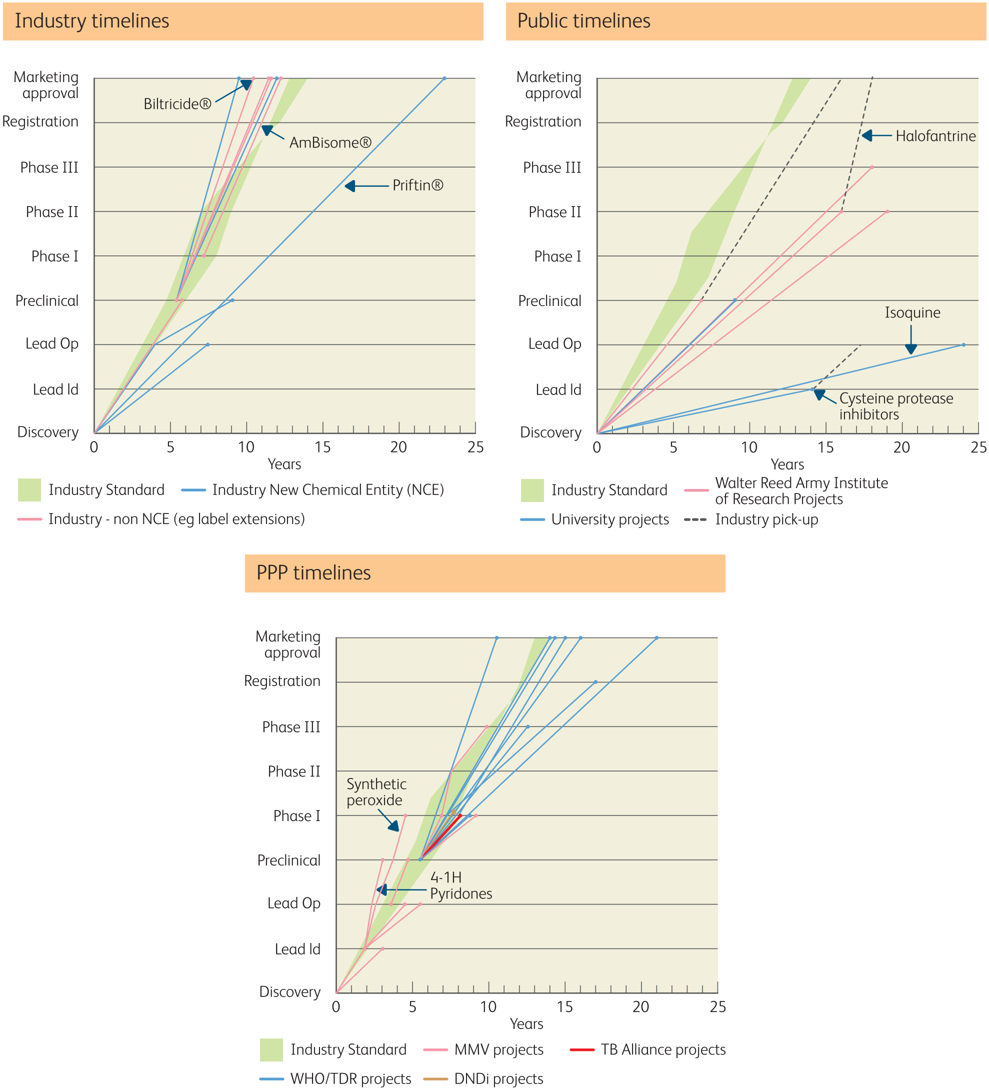
Box 3.8 Examples of PPPs for health and veterinary products funded by DFID

- Global Alliance for TB Drug Development (TB Alliance)
- International AIDS Vaccine Initiative (IAVI)
- International Partnership for Microbicides (IPM)
- Microbicides Development Programme (MDP)
- Medicines for Malaria Venture (MMV)
- Global Alliance for Vaccines and Immunizations (GAVI)
- Drugs for Neglected Diseases Initiative (DNDi)
- Alliance for Livestock Veterinary Medicines (GALVmed)

In 2004 an analysis of drug development projects for neglected diseases revealed that about 75% of projects involved PPPs. Indeed the development of PPPs was a major contributor to the increase in such projects over the previous decade.[51] Further, PPPs, while still largely funded through public sector investment, proved more efficient than wholly private or wholly public ventures on a number of criteria. One of these was the speed of new product development. Figure 3.13 compares the trajectories of development of some selected for neglected diseases under these different mechanisms. The charts show that PPP ventures have timelines of progression through the different stages of drug development and trialling as short or shorter than wholly private ventures and considerably shorter than wholly public ones.

Figure 3.12 – Local researchers in Chennai, India consult with senior TB Alliance executives to further work to better treat and control TB

Figure 3.13 – Comparing drug development speeds through different mechanisms. The y-axis indicates the stages of drug development, with each line representing a different product. It illustrates the time it took to move from a particular stage to a later one. Colours indicate different types of development projects. The green area indicates industry standard development rates for all drugs, not just those for neglected diseases[52]



In drug development PPPs funds are seen more as investments than grants, with projects managed as they would be in an industrial portfolio. Recipients are expected to meet defined benchmarks and pass research results on to the next phase of product development. In exchange for delivering products to developing countries at a reasonable price, the private sector partners can use patents, derived from collaboration, to develop products for more profitable markets in industrialised countries.

An example of one of the first PPPs for neglected diseases is the International AIDS Vaccine Initiative (Box 3.9).

Box 3.9 The International AIDS Vaccine Initiative (IAVI)[53,54]

Figure 3.14 – IAVI scientists working in a laboratory in Kenya

With concerns over the growing HIV pandemic in developing countries, the Rockefeller Foundation convened a conference in Bellagio, Italy in 1994 to address the roadblocks in the development of a vaccine. Participants noted that private pharmaceutical firms had little financial incentive to devote resources to the task, and those that did were targeted at HIV variants present in developed countries.

From these discussions, one of the first PPPs in drug development was formed, bringing together private sector expertise with public sector funding. IAVI, launched in 1996, began by working to generate support for the cause in the international arena. Then, with the help of a wide variety of donors, from governments, to charitable foundations and private companies, the group established a central laboratory in London to coordinate efforts, and set up a network of clinical trial centres in developing countries.

Over the last 13 years, IAVI has worked in partnership with over 40 research, technology, pharmaceutical and government organisations. At first it concentrated on helping with the clinical assessment of vaccine candidates developed by others. IAVI is now looking to improve vaccine design approaches from the start, and has recently opened new laboratories in New York and California. Simultaneously, IAVI is working on building capacity in developing countries to deliver AIDS vaccines once they have proven to be effective and have been approved. With offices in New York, Amsterdam, New Delhi, Nairobi, and Johannesburg, IAVI collaborates with local groups to support AIDS education, engage communities in the vaccine trial process and improve medical infrastructure.

Agricultural PPPs

A small number of agricultural PPPs are also being developed. The African Agricultural Technology Foundation (AATF), a group which works to facilitate the transfer of crop technologies developed by large international organisations to users in Africa, is a particularly successful example (Box 3.10).

Box 3.10 The African Agricultural Technology Foundation (AATF)[55]

Figure 3.15 – Researchers observe local maize taken over by Striga, alongside the healthy new imazapyr-resistant variety

AATF is an African-based and African-led institution established in 2004. It negotiates royalty-free licenses for new proprietary agricultural technologies from corporations and other research organisations. Then, while assuring appropriate stewardship of the technologies, the AATF sub-licenses their use in specific projects by national and international research and development organisations in Africa. So far, five major crop-biotechnology corporations and the USDA have agreed to share their technologies with Africa through the AATF.

Two current projects are:

Striga control: A major pest of staple crops is the parasitic weed *Striga (Striga hermonthica)*, which sucks nutrients from the roots of maize, sorghum and other host crops and transfers toxins to them. The weed is readily controlled by an herbicide, imazapyr, but this kills the crops. Recently, a mutant gene in maize was discovered that confers resistance to the imazapyr herbicide and this is being bred into local maize varieties.[56] The maize seed can then be coated with the herbicide before being planted. In response to germination stimulants from the host plant, the parasitic weed seeds germinate and attach to the maize roots to suck nutrients, including the systemic herbicide from the maize. In the process, the herbicide kills the weed seedling in the ground, allowing maize to grow with little or no impact from the herbicide.

The AATF is facilitating the release of these new maize seeds through public-private partnerships with local and international partners including a number of CGIAR centres, BASF – a private chemical company, the Weizmann Institute of Science in Israel, and local public and private partners in Kenya, Uganda, Tanzania and Malawi. On-farm trials have shown increases in yield from a mean of half a tonne per hectare to over three tonnes.[57]

Cowpea pests and diseases: Cowpea is one of the most important legumes grown throughout the semi-arid tropics of Sub-Saharan Africa. The crop can withstand the hot and dry conditions of the savannah, and is both rich in protein and high in energy, making it an extremely valuable food resource. Unfortunately it is susceptible to a wide-range of pests and diseases which can significantly reduce yields. A variety of insect pests attack the plant at every stage of its life cycle, and a number of fungal, bacterial and viral diseases can add to the damage. The *Maruca* pod borer is particularly problematic, attacking at flowering and pod formation and at its worst reducing yields by 70-80 %.

Researchers at Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) have recently isolated a gene from *Bacillus thuringiensis (Bt)*, *cry1Ab*, and successfully introduced the gene into elite varieties to protect cowpea against the pod borer. This should lead to higher yields and less insecticide use. AATF is providing assistance with licensing, regulation and product stewardship to the partner organisations, which include the CSIRO, International Institute of Tropical Agriculture (IITA), Monsanto, and national research centres across West Africa.[58] One confined field trial has been carried out in Puerto Rico, USA, with indications of successful *Maruca* resistance. The first trials in Africa are planned to take place in Nigeria in 2009.

New platform PPPs

Some partnerships are now being formed to share advances in new platform technologies, such as renewable energy, to communities in the developing world. One such example is the PPP between the German energy company, Energiebau, and a German non-profit capacity building organisation, *InWEnt*, which has been working to install decentralised power systems in rural areas. (Box 3.11)

Box 3.11 German partnership brings the power of 'micro-grids' to rural communities[59-62]

Most rural communities in the developing world are not connected to the electricity grid. They must get their energy from gathering wood or from expensive gasoline powered generators. As expanding the grid in most of these large, relatively sparsely settled areas is not practical or economically feasible, the private German energy company, *Energiebau Solarstromsysteme GmbH*, has worked to design a system of 'micro-grids' which can sustainably supply entire villages, schools or other organisations with electricity.

These innovative micro-grids combine photovoltaic technology with jatropha oil powered generators, thus creating a cost-effective and self-sustaining local system. First, single-axis sun-tracking solar power systems are set up on site, which capture the sun, converting it to electricity. This can then be used, or stored in batteries. Second, jatropha plants, grown locally, are pressed for their oil and used to power retrofitted generators which are used as auxiliary power sources during peak loads or when there is insufficient sunlight.

Jatropha is an inedible plant which can grow in dry soils and therefore does not have to compete with food production. It is high in oil, and provides an alternative to diesel oil which must be transported long distances.

In addition, the plants help to prevent erosion, and are climate neutral, giving as much energy as they take to produce.

One hectare of jatropha can produce one to two tonnes of nuts per year, which when pressed yield around 300 litres of oil, or 600 kilowatt hours.

Energiebau has teamed up with the non-profit, *InWEnt*, also based in Germany, to help deliver the systems to communities and organisations. InWEnt has helped to establish local partners, train groups in the system's installation, operation and maintenance, and worked closely with each community to design the best framework for ownership. So far, the German team has established successful operations in Tanzania, Ghana, Mali, and Indonesia.

Figure 3.16 – A staff member from InWEnt works with the Sisters in Tanzania

In Mbinga, Tanzania, for example, they have set up micro-grids for the Vincentian Sisters, who run schools, health centres and training workshops through their convent. As a result it has allowed them to produce power independently and expand their operations. The same system has also benefitted the local carpenter in Mbinga, who has been able to set up machines to do the work his team had previously done by hand.

5. Conclusion

We tend to think of science and technology for development as a public sector activity, practised largely by developed country scientists working on developing country problems. This model is changing rapidly. Public sector research will continue to play a key role, through new, international science innovation systems and continuing international research institutes. However, the important role of the private sector is emerging through our understanding of how innovation works. New models for PPPs are developing which, in a supportive regulatory climate, allows industry to invest in science for development, even in situations of market failure.

The "northern-driven" nature of this science also needs to change. It must involve local scientists more in innovation systems. This requires a very substantial investment in scientific capacity building to create an equitable research environment, supported by development assistance initiatives that put more research funding under the management of developing country partners.

Finally, research programmes themselves need to be developed more closely with intended beneficiaries, through application of participatory approaches with local, civil society organisations. This will draw local, as well as internationally-gained, knowledge into innovation systems.

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