



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

Papers downloaded from AgEcon Search may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Global agriculture R&D and the changing aid architecture

By

Prabhu Pingali

Presented at the 27th International Association of Agricultural Economists Conference
Beijing, China

August 16-22, 2009

Global agriculture R&D and the changing aid architecture

Prabhu Pingali¹

Agriculture research knowledge and technology that transcends national borders has played a crucial role in enhancing developing country productivity growth over the past fifty years. Modern high yield varieties of rice, wheat and the other major staples are the often cited examples of successful application of global science to address the problems of hunger and poverty. While the initial research investments were made by two International Foundations—Ford and Rockefeller Foundations—a coalition of public and private donors called the CGIAR ensured that such global public good research investments were sustained over the long term. Global plant breeding efforts were successfully diffused at the national level in countries that invested in national agriculture research capacity and created the enabling environment for enhancing productivity growth—hence the Green Revolution.

The comparative advantage of the CGIAR derives partly from the fact that private firms operating thorough markets have limited interest in public goods since they do not have the capacity to capture much of the benefit through proprietary claims. However, once CGIAR generated knowledge, invention and products (such as breeding lines) are publicly available, national public and private sector have responded with investments for technology adaptation, dissemination and delivery. Table 1 provides schematic description of the various stages in the technology research and development pipeline and the role of various players along the chain.

The demand for international agriculture research (IAR) continues to be strong even while becoming increasingly differentiated by the stage of development that a particular country or region is in. The least developed countries (LDCs) and lagging regions in emerging economies continue to rely on the classic role of IAR, i.e., jumpstarting productivity growth in traditional agriculture systems. On the other hand, sustaining productivity gains and enhancing competitiveness is important for post-green revolution agriculture systems in emerging economies, and industrialized economies are becoming increasingly enamored by the multi-functional roles of agriculture. Adapting to climate change is becoming an increasingly urgent concern across all three categories of production systems.

The supply of IAR to developing country research programs is becoming increasingly constrained by: variable donor support; a push towards downstream product adaptation and dissemination activities relative to innovation and product development; and a lack of clear links between international public good research and national agriculture development priorities. The coordination and alignment mechanisms, specified in the *Paris Declaration on aid effectiveness*

¹ Deputy Director, Agriculture Development at the Bill and Melinda Gates Foundation, and Past President of the International Association of Agricultural Economists (IAAE). The views expressed in this paper are strictly personal and should not be attributed to the Foundation.

need to explicitly account for the role of international agriculture research in the development process.

Section 1 of this paper presents a brief summary of the record of past success of the CGIAR and the factors that contributed to it. Section 2 discusses the changing context of global agriculture R&D both from the demand and the supply side. The last section of the paper presents some thoughts on the way forward, specifically in terms of linking global R&D to national needs.

1. Global Agriculture R&D: record of past success.

Although it contributes less than 5% of the total global agricultural research budget, the CGIAR has played a fundamental role in helping spur agricultural growth and poverty reduction in developing countries (Pingali and Kelley 2007). [Evenson and Gollin \(2003\)](#) estimates that the productivity gains from crop germplasm improvement alone averaged 1.0% per annum for wheat (across all regions), 0.8% for rice, 0.7% for maize, and 0.5% and 0.6% for sorghum and millets respectively. The adoption of HYVs during the first thirty years of the Green Revolution, if aggregated across the major crops, rose from 9% in 1970 to 29% by 1980 and reached 63% by 1998 ([Evenson and Gollin 2003](#)).

Studies estimating the rates of return to CGIAR commodity research investments have consistently shown the investment to be extremely profitable. [Evenson \(2001\)](#) and [Alston et al. \(2000\)](#) provide a detailed synthesis of studies conducted across crops and countries. Their reviews confirm the widespread evidence of high economic rates of return for crop improvement research in the CGIAR. Gardner (2003) estimates a b/c ratio of 6.7, just considering efforts on wheat and rice. [Alston et al. \(2000\)](#) in their assessment of trends and characteristics of the rates of return in agricultural research and development examined 292 case studies with 1900 estimated rates of returns. The median annual rate of return estimate from these studies fell within 40–60% – consistent with the broad literature. More importantly, they found no evidence that rates of return to agricultural research had declined over time. [Evenson \(2001\)](#) in his review of over 100 studies estimating rates of return to research came to a similar conclusion.

Determinants of success

Clear demand for specific technologies:

In the early years of the Green Revolution the demand for enhancing food productivity through agricultural intensification was clear, especially for land scarce, labor abundant economies. Hence the emphasis on high yielding staple crops such as rice and wheat, by the International Rice Research Institute (IRRI) and the International Maize and wheat improvement center (CIMMYT), the forerunners of the CGIAR. The agriculture R&D pipeline that effectively captured international innovation & incorporated it into the work of national breeders was driven by the need to achieve food self sufficiency and food security. Such clarity of demand for global agriculture R&D was unprecedented and has not been observed in subsequent decades. Post-Green Revolution challenge of sustaining productivity and reducing environmental externalities

leveraged global R&D to much smaller degree than during the Green Revolution period. Climate change could be different it could drive the demand for global R&D, to help tropical agriculture systems adapt and contribute to mitigation efforts.

Market failure in agriculture R&D:

The most important past successes (in terms of agriculture R&D translating into productivity growth and social impact) have occurred when the market failures in the supply of agriculture technologies were juxtaposed against high demand for productivity growth. Investing in productivity growth for staple cereal crops, such as rice and wheat, in subsistence systems of developing countries was not seen as a profitable venture by the private sector, despite the urgent need for enhancing food supplies. Public sector research investments, at the international and national level, helped fill the gap, this was particularly important for smaller countries where the market for agriculture R&D products was limited. Market failures in agriculture R&D continue to persist in developing country agriculture today, particularly for self pollinated crops for which the rents from research investments are difficult to capture, even where the private sector is becoming increasingly active in more commercially amenable crops, such as hybrid maize and vegetables. Market failures are also observed for research on marginal production environments, such as drought prone environments, where subsistence systems continue to prevail and the risks of research failure are high. Application of IPRs may also distort research priorities such as when private companies choose to invest in commercial crops and neglect pro-poor orphan crops. This is especially important given that six companies hold 75percent of all agricultural patents increasing the risk of non-delivery of agricultural inventions to the poor (Muraguri 2006).

Focus on international spillovers:

Global agriculture R&D efforts have been most successful when they were sharply focused on products that were widely applicable and transcended national and continental barriers. Such international spillovers are highest for a commodity like wheat, which is grown in relatively homogeneous production environments, with little variability in local tastes and preferences for quality characteristics [Byerlee and Traxler (2001)]. On the other hand for rice and maize, while spillover benefits in pre-breeding materials and breeding lines are high, spillovers of final products is significantly lower than for wheat. Quality characteristics are a limiting factor in the direct transferability of varieties for the above commodities. Consumer tastes may be so highly location specific in some cases, such as beans in Africa, to make it difficult even for country programs to develop widely accepted varieties [Sperling, Loevinsohn and Ntambovura (1993)]. NARS programs have generally used varieties or crosses made in the CGIAR centers as parents for the development of varieties that are more closely adapted to particular agro-ecological environments or specific taste preferences (Pingali and Kelley 2007).

National research capacity to adapt international research flows to local conditions:

A large proportion of varietal transfers take the form of adaptive transfers, where advanced breeding materials are adapted to particular production environments. The CGIAR has contributed significantly to the improvement of research efficiency and to the reduction of research costs by enabling such adaptive transfers (Pingali and Kelley 2007). It often takes a long time for knowledge to be developed through research and then adopted. Typically, ten years pass from the initiation of a research project to the dissemination of research results. By borrowing research results (e.g., plant lines or varieties) from other countries, a country can shorten its

research time and contribute to increased returns to research investments [Alston, Norton and Pardey (1995)]. The CGIAR's numerous crop improvement networks allowed for the best breeding materials and knowledge to be widely and freely available across the developing world. Moreover, the expanding pool of genetic resources and varieties made available to the national programs through the CGIAR helped avoid the diminishing returns to breeding efforts that would have occurred in the NARS programs had they been forced to work with the pool of genetic resources available to them at the beginning of the period Evenson and Gollin 2003). None of this would have happened without investments in NARS capacity.

The CG model did not work everywhere

Limited success in generating International Public Goods in Natural Resource Management (NRM) research:

Unlike the case for crop genetic improvement, the documented evidence of the impact of NRM research in the CGIAR is extremely limited, at least when considering moderate to large scale effects [Pingali and Kelley (2007); Kelley and Gregersen (2005)]. A review of the literature by Pingali (2001) found relatively few 'crop management and improved input use' and other NRM-related CGIAR impact studies to-date, a finding that corroborates an earlier review by Byerlee and Pingali (1994). Raitzer (2003) systematically reviewed and evaluated IA studies of economic benefits derived from CGIAR innovations (known 'success stories'), so as to produce a range of plausible and highly credible benefit cost ratios for the entire investment in the CGIAR. Results show a notable absence of large-scale success stories for NRM, with notable the exception of biocontrol and integrated pest management (IPM) research [e.g., Zeddies et al. (2001); Bokonon-Ganta, DeGroote and Neuenschwander (2001)]. A comprehensive survey of rates of returns for all types of agricultural research, including large and small-scale studies, found few NRM-related studies among them, indeed less than 4% of the total studies reviewed [Alston et al. (2000)]. Unlike the case for crop germplasm improvement, for which large-scale adoption of yield-enhancing CGIAR-derived varieties has been documented for a range of CGIAR crops, there are as yet few examples of widely adopted CGIAR-generated improved NRM technologies for which demonstrable impact has been measured. The NRM IAs included in the Alston et al. study also showed significantly lower average rates of return than for crop germplasm improvement research. The reason for there being so few documented success stories of NRM research in the CGIAR, i.e., studies that go beyond anecdotal evidence and selective small-scale case study results, is not yet clear. The highly location-specific nature of NRM technologies and the limited role of international spillovers, beyond principles and paradigms, could partially explain their limited success.

Marginal environments & orphan crops:

Low rainfall drought prone environments, submergence prone areas, lands of low soil fertility are examples of marginal production environments in which the CGIAR has made limited progress in enhancing productivity. Similarly, its crop improvement efforts have had relatively lower success in the case of the so called orphan crops such as sorghum, millets, cassava, tropical legumes, etc. Part of the reason for the limited success is that unlike the case of wheat and maize, orphan crops have had no research from OECD countries to draw upon. Same is the case for research on understanding marginal tropical production systems. A significantly longer

term commitment needed to be made if success in the above crops and environments was to be assured, especially given the relatively higher risk of hitting dry wells. The CGIAR's limited success in sub-Saharan Africa is at least partially related to the predominance of marginal production environment in the region.

2. Changing context of global agriculture R&D

Evolving nature of demand for agriculture R&D

The demand for international agriculture research (IAR) continues to be strong even while becoming increasingly differentiated by the stage of development that a particular country or region is in. The least developed countries (LDCs) and lagging regions in emerging economies continue to rely on the classic role of IAR, i.e., jumpstarting productivity growth in traditional agriculture systems. On the other hand, sustaining productivity gains and enhancing competitiveness is important for post-green revolution agriculture systems in emerging economies, while industrialized economies are becoming increasingly enamored by the multi-functional roles of agriculture. Growing public concerns with environmental sustainability, food safety, trans-border disease control are leading to renewed attention to the role of the IAR in helping identify and promote suitable solutions. Adapting to climate change is becoming an increasingly urgent concern across all three categories of production systems, here again the contribution of IAR in developing technologies for adaptation and mitigation is being urgently sought.

Changing market failure conditions by stage of development

Private sector investment in agriculture R&D has been rising for the increasingly marketed oriented production systems in emerging economies. Large multi-national corporations partnering with national agriculture companies are becoming a viable alternative to public sector technology transfer, especially in the case of high value agriculture (cotton, vegetables, livestock, etc) and hybrids of staple crops, such as maize. The ability to capture the rents from agriculture R&D investments, through the use of IPR and through the development of hybrids, has lead to the changing locus of agriculture research towards the private sector (Pingali and Traxler, ----).

An enabling policy environment that includes intellectual property protection, reduced trade barriers, and a transparent bio-safety procedure will lead to further private sector research investments for commercial production systems in the countries that are well into the transformation process. However, large areas of the developing world, especially sub-Saharan Africa, remain outside the orbit of private sector interest. The private sector is also unlikely to invest in research for difficult growing environments, such as drought prone or high temperature environments, even in transforming economies. The private sector's record in delivering NRM technologies is also limited, even in advanced country agriculture. Public sector research investments ought to be partnered with the rapid progress being made by the private sector in order to meet the needs of the poor (FAO, 2004).

Changing Aid architecture

The nature of overall aid supply to developing countries has been changing dramatically over the past decade, in terms of the quantities provided, the plurality of funding sources, and donor coordination and alignment mechanisms. These changes have significant implications for the way IAR is conducted and transferred to developing countries. A recent ODI report indicates that total aid volumes have risen from around 60 billion dollars per year in the 1990s to around a 100 billion dollars in 2005 and are anticipated to rise to 130 billion dollars by 2010 (Burall et al., 2006). Averaged across OECD countries, ODA as a percentage of Gross National Income has risen back to 0.33 in 2006 after having dropped to a low of 0.22 in 1997 (OECD/DAC, 2006). New donor countries, such as China, India, Korea, as well as Private Foundations (such as the Gates Foundation) and multi-lateral funds (GEF), have added to the overall aid totals. Growth in the volume of aid, the number of donors, and multiplicity of agendas has lead to calls for greater coordination and alignment of donor support at the country level.

The Paris Declaration on Aid Effectiveness, sponsored by the Development Assistance Committee (DAC) of the OECD, has been a significant step in the direction of enhancing donor coordination. Donors, who signed on to the declaration, agreed to follow government plans and priorities (alignment) and to work together in that process (harmonization). The Paris Declaration emphasizes budget support to priority programs at the country level rather than support for discrete projects that may or may not be part of the government plans and priorities. While there are questions about whether the Paris Declaration is implementable I will not dwell on them, in this paper my concern rather is with the implications for IAR.

Do the above efforts contribute to the promotion of trans-national public good research and strengthen the R&D pipeline for farm level impact? There are several reasons to be concerned. First, there are no obvious mechanisms for national plans and priorities to take into account what's coming down the global agriculture R&D pipeline. Second, national priorities will tend to be focused on downstream, highly adaptive activities, rather than public good research. Third, scale economies in technology generation may be lost, as countries may embark on parallel efforts around similar problems. Fourth, the CGIAR itself may move more downstream (playing a development role) in several countries in response to donor support for country level activities, sacrificing its traditional role as a generator of international spillovers. Finally, current parallel efforts towards increased harmonization of IAR (CGIAR reform) do not take into account donor efforts to align with and support national plans and priorities. So, while the movement towards national ownership of its development agenda and donor alignment around it is unquestionably good, an unintended consequence could be a break in the R&D pipeline that supplies public good research and technologies for enhancing developing country agriculture productivity growth.

3. The way forward – linking global R&D to national needs

Stratify by stage of development

The role and contributions of IAR to developing country agriculture will vary significantly by the stage of development that a particular country is in. For countries at the low end of the structural transformation process, mostly countries in sub-Saharan Africa, the CGIAR's traditional focus on food staples will continue to be very important. Broad based productivity gains in staple crops can have far reaching impacts on the rural poor (Binswanger and McCalla, 2009). The task of course continues to be daunting given heterogeneity of crops and production environments, and high exposure to climatic risks (which could get worse), low levels of investment in infrastructure and agriculture research capacity, and a poor enabling environment for enhancing productivity growth. For emerging economies, on the other hand, the CGIAR could capitalize on the growing strength of the National Research Systems and the private sector and focus its efforts in areas where it can provide unique international public goods. In the case of favorable production environments, pre-breeding materials for shifting yield frontiers for the major staples, managing transboundary pests, and sustaining intensive production systems, are some of the areas that the CGIAR could continue to be important. Focused research on stress prone environments (for example, drought and high temperature) is crucial not just from an equity point of view, but also as part of an overall strategy to develop technologies that can adapt to higher temperatures and more variable climatic conditions.

Technology Demand Assessment

As pointed out in section 1, one of the reasons for the early success of the CGIAR was that it responded to clear global demands for enhancing staple food crop supplies through intensification and agriculture productivity growth. Today, the articulation of demand is much more diffused and there is significant lack of clarity on what is needed and what can be delivered through global public R&D. Identifying mechanisms for assessing technology demand at the national and regional level and from there deriving and prioritizing global public good research ought to be a major priority for the CGIAR.

Much of the discussion on assessing technology demand and preferences has been done at the community level using a variety of participatory methods (see Pingali, et al. ----; IAASTD 2008). Farmer associations have also been involved in making decisions on the allocation of research funds, as in the Yaqui Valley of Mexico ([Ref](#)). Eliciting farmer voice in priority setting is important at the more applied and adaptive end of the research pipeline and for eliciting preferences on technology design. However, aggregating across farmer preferences and eliciting information on strategic longer term research priorities has been a challenge with the exclusive reliance on participatory methods.

There are other emerging tools and approaches that can help assess technology demand at the national and regional level and effectively used by the CGIAR for its priority setting and targeting its global public good research efforts. The World Bank's Living Standards Measurement (LSMS) group is embarking on a massive household panel survey across sub-Saharan Africa, with a focus on rural households. This Nationally representative household survey will provide a wealth of information on the state of African farming systems, technology use, their constraints to enhancing productivity growth. The LSMS data can be invaluable in generating analysis and discussions on national level research priorities and technology demands. Since the LSMS surveys are standardized across countries, aggregation at regional levels is also possible, hence the ability to derive trans-national research demands. IFPRI's "Harvest Choice" data platform provides spatially disaggregated data on a variety of variables that are important for assessing technology demand. Agro-climatic, biophysical and socioeconomic data can be overlaid to identify priority constraints at the sub-national, national and regional levels, and to target technology diffusion appropriately. The Harvest Choice platform allows for an ex ante assessment of potential technology interventions at the national and sub-national levels. Information from the Harvest Choice analysis can be used for an ex ante assessment of potential technologies at the global level and over time by using IFPRI's IMPACT model which is also being revamped for better serving this role.

Supply assessment - Focus on market failures

The wealth of data and analysis generate through the above efforts would only be useful if it fed into decisions on relative roles and priorities for national research systems, private sector, and the CGIAR. Table 1 provides a basis for identifying differentiated roles for the various actors along the R&D pipeline. The emphasis for the CGIAR should be on focusing on areas where market failures in the supply of R&D are prevalent. As discussed earlier, these are usually subsistence production systems, in highly stress prone environments, growing orphan crops. Technology invention and product development for self-pollinated crops (such as rice and wheat) would also be market failure cases that warrant high levels of CGIAR involvement even in favorable (and commercial) production environments. In both cases, international research ought to be focused on generating public goods and strengthening national partners for enhancing local adaptation and diffusion. For example, the generation of maize breeding lines that are tolerant to drought is a clear global public good, while the development of hybrids for use in a particular country or region is not.

Clear link between the international R&D and national strategy

The challenge for the new aid architecture is to create mechanisms for better linking international R&D and national agriculture development strategy. Even within a country the process for identifying technology needs and prioritizing them for budget support is limited. As a result R&D activities continue to be undervalued in national strategies and donor priorities. Vernon Ruttan had suggested, over two decades ago, the formation of "National Research Support

Groups” that would assess and prioritize research demands and champion their supply at the national level (Ruttan 1987). The research groups would also be a conduit for linking national R&D with the international research pipeline. Data and analysis generated through the LSMS, Harvest Choice and other initiatives discussed above could strengthen the ability of the national research groups to identify priority problems and to identify potential solutions on the global R&D pipeline, and coordinate their adaptation and diffusion at the national level. Finally, the research groups could achieve a regional and continental voice by working collectively in regional groupings such as: the Southern African Development Community (SADC) or ECOWAS, the Economic Community for West African States.

Continuing relevance of dedicated vertical funds

The new aid architecture is focused on a “horizontal” country based approach to aid. While a discussion of the merits of the horizontal approach is beyond the remit of this paper, I argue here that the “vertical” approach continues to be relevant for global R&D. The challenge is to create synergies between the two approaches.

“Vertical funds” or “global programs” are defined as partnerships and related initiatives whose benefits cut across more than one region of the world. In other words, global programs focus vertically on specific issues or themes that cut across countries (IDA, 2007). Incidentally, the first major global program was the CGIAR, established 37 years ago. Since then there have been many more such programs in health (Global Fund for AIDS, TB and Malaria; GFATM), environment (GEF), etc. Lele (----) argues that global programs are the right choice when: i) they generate global public goods – products, services, or policy regimes – at the global level and their benefits spill across national boundaries; ii) they provide benefits that the members engaged in the partnership could not deliver if they acted alone; and iii) they provide additional financial and political resources whose benefits outweigh the increased management and financial burdens they place on the partners and the developing countries they intend to benefit.

It is hard to imagine a sustainable global public good pipeline of agriculture research products without a dedicated vertical fund that is committed to for the long term. To make it truly effective, in terms of achieving impact on developing country agriculture, it would need to specify: sharply defined outputs that it is focused on; an ex ante assessment of their impact on target populations; and clearly defined indicators for evaluating progress and measuring ultimate impact. Sequenced funding along the R&D pipeline requires synergies between the global “vertical fund”, that generates innovations, and national level “horizontal funds”, that can be used for technology adaptation, dissemination and delivery. Ultimate impact on developing country farmers depends on these synergies.

References

Alston, J.M., Norton, G.W., Pardey, P.G. (1995). *Science under Scarcity: Principles and Practices for Agricultural Research Evaluation and Priority Setting*. Cornell University, Ithaca.

Alston, J.M., Marra, M.C., Pardey, P.G., Wyatt, T.J. (2000). “Research returns *redux*: A meta-analysis of the returns to agricultural R&D”. *Australian Journal of Agricultural Resource Economics* 44 (2), 185–215.

Binswanger, Hans P., and Alex McCalla (2009). The changing context and prospects for agriculture and rural development in Africa. (Forthcoming) *Handbook of Agricultural Economics*, Volume IV. Elsevier Press.

Burall , Simon and Simon Maxwell (2006). Reforming the international aid architecture: options and the way forward. Working Paper 278. ODI, London, UK.

Byerlee, D., Pingali, P. (1994). “Rice research in Asia: Fulfillments and frustrations”, Proceedings of the XXII Conference of the International Association of Agricultural Economists in Harare, Zimbabwe, 22–29 August 1994.

Byerlee, D., Traxler, G. (2001). “The role of technology spillovers and economies of size in the efficient design of agricultural research systems”. In: Alston, J., Pardey, P., Taylor, M. (Eds.), *Agricultural Science Policy: Changing Global Agendas*. Johns Hopkins University Press, Baltimore.

Bokonon-Ganta, A.H., DeGroote, A.H., Neuenschwander, P. (2001). “Socioeconomic impact of biological control of mango mealybug in Benin”. *Agriculture, Ecosystems and Environment* 1905, 1–12.

Evenson, R.E. (2001). “Economic impacts of agricultural research and extension”. In: Gardner, B., Rausser,G. (Eds.), *Handbook of Agricultural Economics*, vol. 1. Elsevier Science, Amsterdam. Ch. 11.

Evenson, R.E., Gollin, D. (Eds.) (2003). *Crop Genetic Improvement and Agricultural Development*. CABI.

FAO (2004). *State of Food and Agriculture 2003/04 – Biotechnology: meeting the needs of the poor*. FAO, Rome, Italy

IDA (2007). Aid architecture: an overview of the main trends in official development assistance flows. International Development Association. Resource Mobilization (FRM).

Kelley, T.G., Gregersen, H. (2005). “Lessons from CGIAR impact assessment research”. In: Shiferaw, B., Freeman, H.A., Swinton, S. (Eds.), *Natural Resource Management in Agriculture: Methods for Assessing Economic Environmental Impacts*. CABI Publishing, pp. 341–360.

Lele, Uma., Nafis Sadik, and Adele Simmons (2---). The changing aid architecture: Can global initiatives eradicate poverty?

Muraguri, Lois. 2006. Private rights and public goods: conflicts in agriculture R&D.

Pingali, P.L. (2001). Milestones in Impact Assessment Research in the CGIAR, 1970–1999, with an Annotated Bibliography of Impact Assessment Studies Conducted in the CGIAR, 1970–1999. Standing Panel on Impact Assessment, Technical Advisory Committee (TAC) of the CGIAR, World Bank, Washington, DC.

Pingali, Prabhu L., Scott D. Rozelle, Roberta V. Gerpacio (2001). The Farmer's voice in priority setting: a cross country experiment in eliciting technology preferences. Economic Development and Cultural Change.

Pingali, Prabhu., and Tim Kelley (2007). The role of international agriculture research in contributing to global food security and poverty alleviation: the case of the CGIAR. In the Handbook of Agriculture Economics, Volume III. Elsevier Press.

Pingali, P.L., and G. Traxler (2002). Changing locus of agriculture research: will the poor benefit from biotechnology and privatization trends? Food Policy 27, P 223-238.

Raitzer, D. (2003). "Benefit–cost meta-analysis of investment in the Consultative Group on International Agricultural Research (first draft)", Report prepared on behalf of CGIAR Standing Panel on Impact Assessment. Science Council Secretariat, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 45 pp.

Ruttan, Vernon (1987). Agriculture Research Policy. University of Minnesota Press.

Sperling, L., Loevinsohn, M., Ntambovura, B. (1993). "Rethinking the farmers' role in plant breeding: Local bean experts and on-station selection in Rwanda". Experimental Agriculture 29, 509–519.

Zeddies, J., Schaab, R.P., Neuenschwander, P., Herren, H.R. (2001). "Economics of biological control of cassava mealybug in Africa". Agricultural Economics 24, 209–219.

Table 1
Stages in Technology Generation and Sources of Supply

Stages	Examples	Cross national spillovers	Suppliers	Funders
Pre-technology Sciences	Plant physiology, genetics, molecular biology, etc	Very High	Universities, Advanced research labs	Foundations, Governments
Agriculture Knowledge generation & technology invention	Gene Discovery, Genetic transformation, Bio-informatics	High to moderate	Universities, Advanced research labs, CGIAR, MNCs, Advanced NARS	Foundations, OECD countries, MNCs, Multilateral organizations
Product development & adaptation.	Pedigree breeding lines, Hybrid parental lines, Multi-location testing, Variety/hybrid development	Moderate to low	CGIAR, AGRA, Regional organizations/networks, Advanced NARS, International NGOs, Multinational & national private sector	Foundations, bi-lateral donors, multilateral donors, private sector, INGOs, Venture Philanthropists
Dissemination & delivery	Variety/hybrid release, seed/input delivery, extension	Low	NA RS, National Private sector, NGOs	Foundations, bi-lateral donors, multilateral donors, private sector, INGOs, Venture Philanthropists
Policy Environment	Seed, infrastructure, markets, trade, credit, price policies	Low	Regional organizations, CAADP, National governments, policy think tanks	