



Assessing the role of international agricultural research in poverty alleviation from an innovation systems perspective

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1. Introduction

The role of agriculture in development and poverty alleviation, including that of agricultural research, has been reevaluated in recent years (World Bank 2007). The discussion, however, has not yet fully addressed how globalization, migration and new technologies have changed the dynamics of poverty and the organization of science, and what role formal research, including the CGIAR, should play in the new juncture.

The Consultative Group on International Agricultural Research (CGIAR) is an informal alliance of about 60 international donors (including governments from developed and developing countries, private foundations and multilateral organizations) that support 15 international agricultural research centers. The first two centers in the system (CIMMYT and IRRI) created the high yielding varieties that were a key factor in the Green Revolution.

Poverty alleviation has two benchmarks: achieving food security and affording a healthy life. In the past, greater productivity of food crops resulting from input-intensive technologies was seen as the main tool to achieve both goals; this view was supported by the success of the

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Green Revolution in Asia. This is no longer the case. An increasing share of rural households derive most of their income from off-farm employment (World Bank 2007); for them food security depends more on access to labor markets and on the price of staples than on their own food production. For those households that still rely mostly on staple production, food security still depends on higher yields, but for most of them, it will not be the path out of poverty (see section 2). On the other hand, higher yields can eliminate poverty for those small farmers who can make the transition from subsistence to commercial agriculture. Recent studies seem to indicate, however, that only a small share of rural households can make this transition (Ekboir et al. 2008).

The substantial reduction in poverty observed in the last two decades resulted from rapid growth enabled by integration into globalized markets and from remittances from migrants and not from the expansion of staples in small farms (World Bank 2005; IFAD 2008). Commercial agriculture played an important role in this process. Its expansion resulted from the use of commercial and production technologies generated by private firms and sometimes by NGOs. International and public research institutions contributed little to the process. As the limited contribution of public research to agricultural development became evident, donors started to question the effectiveness of their contributions to agricultural research, including the CGIAR and developing countries' research institutions (Byerlee, Alex and Echeverria 2002).

The questions about the CGIAR's effectiveness also reflected a better understanding of the links between formal research and innovation. The literature on innovation processes and the theories of complexity have shown the limitations of the linear vision of science, and have identified new instruments to foster economic and social development. For several reasons, however, the CGIAR has not been successful enough in adapting to the new environment. First,

in contrast to what happened fifty years ago, there is no clear model of what role modern technologies should play in development, in particular, because there are no clear recipes for development (Rodrik 2006). Second, it has been accepted that the joint dynamics of agriculture and poverty have changed (see section 2), but it is not clear what role the CGIAR should play in poverty alleviation. Third, because the CGIAR is composed of a large number of actors, each with his/her own agenda, it is difficult to agree on and implement substantial changes in a system with diffuse governance mechanisms. Fourth, the CGIAR's existence was justified as a source of international public goods. When the linear model of science was shown to be incorrect, the idea of scientific public goods as a source of economic growth was also questioned (see section 3.3).

The remainder of this paper is organized as follows. Section 2 reviews the new dynamics of agriculture, especially the impacts of globalization, high value markets and remittances. Section 3 examines some recent advances in the literature of innovation systems and complexity theories, while section 4 presents a stylized picture of changes in research systems. Section 5 discusses the CGIAR's current role and section 6 presents some ideas to adapt the system to the needs of twenty first century agriculture.

2. The new dynamics of agriculture and rural poverty

Globalization, technical change and migration have substantially transformed the joint dynamics of agriculture and poverty in developing countries. Prior to the 1980s, poverty was closely linked to agriculture. Since most countries were in the initial stages of urbanization and travel was difficult, farming families worked mostly in rural areas and derived most of their income and food from agriculture. It was only natural to expect that poverty alleviation and growth in agricultural-based countries would come from increased agricultural productivity (see, for example, World Bank 2007), which was concentrated in staples and a few export products.

Agricultural development programs were based on the assumption that productivity jumps could only come from “modern” technologies, designed by scientists and “transferred” by extension agents (World Bank 2006). In this framework, the greatest limitation to agricultural growth was insufficient access by farmers to technical information. Important investments were made in research and extension services, that specialized in a few grains, livestock and sometimes dairy (Byerlee, Alex and Echeverria 2002). The success of the Green Revolution in South Asia was seen as confirmation of this model. It was not recognized until recently that the impacts of the Green Revolution could not be attributed only to science but to a package that included major investments in infrastructure and subsidized inputs and outputs (Morris and Byerlee 1998).

After the crisis of the 1980s, most developing countries implemented structural adjustment programs, which included market liberalization, downsizing the public sector and opening new activities to the private sector (Staatz and Eicher 1998). Helped by the new institutional environment, multilateral trade agreements and novel technologies, agriculture in Latin America and Asia grew rapidly. Expansion of smallholder commercial agriculture in sub-Saharan Africa started in the 1990s. In 2004, exports of high value agricultural products accounted for 43% of agrifood exports from developing countries (World Bank 2007).

Prior to the 1980s market imperfections, insufficient infrastructure and economies of scale limited small farmers’ access to input and output markets (Staatz and Eicher 1998). With deregulation, domestic and international markets became more integrated, diversified and sophisticated, which opened new opportunities and created new challenges for farmers in developing countries.

Technical change in production, post-harvest, transportation and marketing enabled the expansion of agricultural markets and the emergence of high value agriculture. Most technologies for high-value products were imported and adapted to local conditions by private firms or NGOs (Reardon 2005) Multinational companies sold worldwide the products they developed in their central laboratories, allowing commercial farmers access to the latest inputs. The public research and extension institutes from developing countries, in general, did not participate in the expansion of the most dynamic markets, but some researchers participated as individuals (Ekboir et al. 2008). Although the public research institutes continued to work mostly in their traditional lines of research, some opened programs in high-value products. Many CGIAR researchers participated in international networks that developed important technological packages for traditional products (see, for example, Ekboir 2002 and Gabre-Madhin and Haggblade 2004). In other cases, they were instrumental in the development of niche markets (e.g., Papa Andina). Their contribution to poverty alleviation, however, seems to have been limited because few small farmers have been able to escape poverty producing cereals, or because niche markets by nature cannot be massive (see below). The limited participation of the CGIAR and public research institutions in the most dynamic agricultural markets led many stakeholders to question their role in poverty alleviation.

Local markets for traditional agricultural products also became integrated into international markets through imports. Small farmers suddenly had to compete with foreign farmers, even if they continued doing what they had been doing for generations. The external competition reduced the profitability of traditional products, especially for small farmers who did not introduce more intensive technologies. Contrary to what was expected, many small farmers continued producing traditional products despite the strong competition from imports. The most

accepted explanation for this phenomenon is that poor rural families derive only a small percentage of their income from agriculture, with off-farm employment and remittances being the main sources of earnings (Taylor, Dyer and Yunez-Naude 2005). These families still live in the land, but farm only to secure their supply of staples or to produce specialty products that cannot be easily bought and are needed for traditional foods. Thus, the price elasticity of their production is very low. Higher productivity is still important for the poorest of the poor who have limited insertion in labor markets. For these households, higher yields reduce food insecurity although it is highly unlikely that they will lift them out of poverty.³

Local and distant labor markets also became more integrated. Easier travel and improved financial services meant that people from rural areas could work in distant locations and send remittances back home. The livelihood strategies of most poor rural households are now more diversified, with non-farm income increasing faster than farm income (World Bank 2005; Holden, Shiferaw and Pender 2004). In fact, there is mounting evidence that for many rural households increasing agricultural productivity has become less relevant than expanding other sources of income (World Bank 2007; Barrett, Reardon and Webb 2001; Davis et al. 2000).

In fact, domestic and international migration is becoming the cornerstone of the livelihood strategies of many rural households (Vargas-Lundius 2004). It is estimated that in 2006, 150 million international migrants sent home US\$300 billion (IFAD 2008). It has been consistently found that remittances reduce poverty (Özden and Schiff 2006; López-Córdova and Olmedo

³ For example, maize produced under rainfed conditions with a good technology for small farmers can yield about 7 ton/ha. At the price of 450 dollars per ton, it would generate a revenue of \$3150 per ha. After deducting all costs, the net income would still not be enough to lift the household out of poverty.

2006), and that most remittances are invested in education and health (i.e., in human capital that can be used in off-farm employment), housing and only a small proportion in expanding agricultural production (López-Córdova and Olmedo 2006; Davis et al. 2000). The reasons for these investment preferences are poorly understood but they are an indication of the limitations of traditional development policies (including agricultural research and extension) aimed at increasing the agricultural output of most poor rural households.

It has also been found that the most effective way to reduce poverty is through economic growth (World Bank 2005). In other words, programs to increase agricultural productivity among poor farmers have a smaller effect on poverty than support to rapidly expanding markets combined with programs to facilitate integration of poor households into markets, either as producers of high value products or as specialized workers.

This rapid review shows that many of the assumptions that justified the creation of the CGIAR are no longer valid. The changes in the global economy and in technologies had major consequences for the global research system, especially for the perception of the role agricultural research should play in poverty alleviation. The global surplus of cereals and the expansion of global food markets until recently showed that hunger was not caused by insufficient production but by the poor's inability to buy food, and that food security was not equivalent to food self-sufficiency (both at the national level and the level of the poor households). It also became apparent that small farmers would not escape poverty by producing staples in small plots, but by integrating into high value markets or by working off- farm.⁴ In some cases higher productivity of staples triggered a virtuous cycle; because poor rural households needed to allocate fewer

⁴ Although more productive small farmers would still be poor, they would be better fed.

resources to food production, they could start new income generating activities (Ekboir, Boa and Dankyi 2002). But these households were better off only if they diversified out of staples.

3. The nature of innovation processes

Innovation depends both on motivation and ability (Christensen, Anthony and Roth 2004). Globalization, technical change and better infrastructure create opportunities when they link rural agents (including farmers) to markets. But to take advantage of these opportunities, these agents have to develop appropriate capabilities. This section reviews the complex nature of innovation and of innovative capabilities.

3.1 What is a complex process?

Traditionally, researchers and policy-makers thought of natural and social processes as mechanisms that could be controlled by pulling the appropriate levers; this vision has been challenged by complexity theories that posit that these processes behave more like living organisms that can be influenced but not controlled (Crutchfield and Schuster 2003). The most relevant type of complex systems for the analysis of the CGIAR is formed by many different independent decision-makers (for example, directors, managers, employees, clients and suppliers), multiple interactions, many feedback mechanisms and random processes. Such systems are known as complex adaptive systems (CAS) (Kauffman 1995).

Because of its decentralized nature, no single agent can manipulate a CAS or predict how it will evolve; therefore, new approaches are needed for planning and policy-making. There are several methods to do this and discussing them exceeds the scope of this paper (for a detailed discussion see Axelrod and Cohen 1999 and Crutchfield and Schuster 2003). One way to influence a CAS is to operate on the dynamics of evolution, especially variation and selection. For example, a plant breeder knows the characteristics of the parents available to her and selects

those she hopes will pass some desired trait to their progeny (e.g. resistance to a given disease). In the early stages of developing a new variety, the breeder usually makes thousands of non-naturally occurring crosses. In other words, the breeder *increases variety* by making crosses she hopes will raise the probability of obtaining the desired result (as opposed to the totally random crosses that occur in nature). With *artificial* selection, the breeder overrides the natural process of selection via reproductive efficiency by selecting the progeny that displays the desired properties without taking into account their reproductive efficiency.

The latter example illustrates a key characteristic of operating on a CAS: contrary to what an engineer (or a researcher working with traditional methods) would do, the “solutions” to “problems” are obtained through a process of directed search without designing them intentionally. On the other hand, scientists who use a *rational design* approach start by building a detailed model of the problem, and then design a structure that can serve as a solution. The relative efficiency of each method depends on the complexity and stability of the processes upon which it operates and how much is known about them. If little is known, if it changes rapidly or is complex, rational design is less effective because it limits the exploration of the solution space and bets that the explored solution is the most effective. In these cases, the effectiveness of the rational design approach depends more on luck than the management of variety and selection approach. It has been demonstrated that the latter converges on an optimum at least as quickly as the rational design method (Crutchfield and Schuster 2003).

3.2 What do we know about innovation?

We define an *innovation as anything new successfully introduced into an economic or social process*. Major innovations combine a business model and a technological package

(Davila, Epstein and Shelton 2006). Innovations that do not include both components result in minor improvements along an established technological trajectory.

A consequence of our definition is that researchers do not generate innovations but information, either codified (e.g., a paper or blueprint), embedded (e.g., an improved seed) or tacit. This information only becomes an innovation when an agent uses it to improve what s/he is doing. Innovators use different sources of information; most of it, however, does not originate in science but in everyday activities and in interactions with other actors (Faberge 2005). Thus, innovative capabilities depend on the agents' absorptive capabilities, i.e., on the agent's ability to use existing information (Cohen and Levinthal 1990). Rapid adoption of new technologies is not necessarily associated with large expenditures on research and extension, but with the development of absorptive capabilities (Ekboir et al. 2008). For this reason, the dynamics of innovation systems do not depend on the agents at the forefront of research and technology development, but on the innovative capabilities of the majority of agents. In other words, it is more important to have many agents searching for and adapting existing technologies than to have a few sophisticated research institutes in a static society.

Because of the exploding volume of information and the increasing complexity of innovations, no agent commands all the resources needed to innovate; therefore, innovators integrate into networks (Powell and Grodal 2005). The dynamics of innovation networks depend on their complexity and maturity. For simple innovations or mature markets, the networks are loose and members interact mostly formally or through markets because each actor understands the needs of other actors. These networks have been the model for most agricultural programs, including the CGIAR. On the other hand, in the case of new or complex innovations, members interact often and informally to overcome unforeseen obstacles and to build confidence. The

need for intense interactions arises because generalized uncertainty about the new technologies and their market potential prevents effective contracting (Christensen, Anthony and Roth 2004).

The effectiveness of innovation networks depends on their ability to facilitate the exchange of information and resources. Technically, this is known as the network's navigability. Navigability depends on the existence of "central" actors (e.g., very connected actors) interacting among them. It has been shown that a few central actors can increase the network's navigability tremendously (Watts 1999).

The emergence and consolidation of innovation networks depends on a number of factors, among which a catalyzing agent is one of the most important (Ekboir 2002). This agent induces other partners to invest time and resources in the network. Once the network is consolidated, the importance of the catalyzing agents diminishes, because other actors are more willing to participate when the benefits of participation become clearer, and the interaction rules are known to all partners. The role of the catalyzing agent is different from that of linking agents. The catalyzing agent facilitates the emergence of the network while the linking agent increases the connectivity, even in mature networks. While the catalyzing agent is essential in the early life of a network, the linking agents are important through the whole process. The CGIAR can play important roles in the emergence and consolidation of innovation networks.

3.3 The nature of organizational innovative capabilities

Organizational capabilities are important because actors seldom innovate in isolation, but rather interacting in formal or informal networks. These capabilities cannot be bought or easily copied; thus, they have to be built with sustained investments, selection of appropriate specialists and project leaders, and strong commitment among the partners (Christensen and Raynor 2003). Organizational capabilities are embedded in individuals and in the organization's technology,

structure, strategies, routines, culture and coordination procedures (Argote and Darr 2000). Even though innovative organizations must have at least a few innovative individuals, this is not required for the vast majority of its members; what is required is that the organizations create an environment in which innovative individuals can express their abilities and influence other members (Christensen and Raynor 2003).

Organizations depend on their innovative capabilities to respond to changes in the technological, economic and social environments. Innovative capabilities are built by learning, i.e., by creating knowledge. The specialized literature differentiates between information and knowledge (Quintas 2000). Information is raw data (e.g., published materials, blueprints or physical objects), while knowledge is the use of the data to create unique interpretations of reality. Because of its personal nature, two actors can learn different things from the same information, or the same thing from different types of information. Knowledge is very difficult to share while information can be disseminated quite easily.

Because the information stock is complex, diverse, short-lived and fast-growing, learning requires strong capabilities to search for useful information and digest it to create knowledge (Ekboir et al. 2008). These absorptive capabilities depend on exogenous and endogenous factors. Economic stability, development, the nature of competition and the interactions between firms and research institutes are important exogenous factors; the endogenous factors include organizational cultures, investments made in the search for and adaptation of information, quality of the personnel and mechanisms to socialize knowledge.

The understanding of organizational innovative capabilities has major consequences for the nature and role of the CGIAR. One of the major justifications for its existence has been the generation of international public goods (Alston, Dehmer and Pardey 2006; CGIAR 2006). The

public goods generated by the CGIAR are technical information, either embodied such as seeds, or disembodied as publications and agronomic recommendations.⁵ Pure public goods do not require any special effort or skill on the side of the receiver of the services of the goods. But to use technical information, innovators have to invest substantial resources to develop absorptive capabilities. In other words, while information may be free, its use is not (Faberger 2005); spillovers only occur when agents have invested in their absorptive capabilities.

4. Changes in the organization of science

Globalization, new regulations and advanced technologies are redefining the international research environment. Increasing interdependence between knowledge-based economies implies an ever-expanding international flow of technology, scientific knowledge and know-how. The better understanding of complex systems and the development of methods to operate on them are also changing the organization of science in four ways. First, the linear vision of science highlighted the preeminence of theoretical research over applied work. The examples presented in section 3.1 show that in fact, both approaches are complementary. Even more, overreliance on theoretical work in a CAS can actually be a hindrance, because it constraints the exploration of new research approaches and potential solutions.

⁵ It must be noticed, though, that a seed is not a public good since it is rival and excludable. The fact that CGAR centers have distributed seeds for free does not change their private good nature. The public good is how to combine parents to develop a particular seed. A similar confusion has been made regarding the public good nature of international germplasm banks. Although these banks serve the whole humanity, they could in principle refuse to give seeds to a particular institution and, since the use of a seed precludes others from using exactly that same seed, they are rival.

Second, research systems must be flexible to react to new problems and research opportunities. But individual institutions cannot react fast enough because of inertias (Christensen, Anthony and Roth 2004). Flexibility can only be achieved with enough variation in the system. In other words, it is necessary to have a system with many good institutions that can form inter-institutional teams to solve emerging problems; in fact, this has been one of the major strengths of the American research system (Kraemer 2006), and one of the major problems the CGIAR faces (see section 5). Third, effective research systems resulted when researchers interacted closely with innovative agents (Dosi, Llerena and Sylos Labini 2006), but the CGIAR has had problems in identifying new partners beyond the National Agricultural Research Institutes (NARIs).

Fourth, formal research has traditionally been conducted by stable teams within an institution and discipline; Gibbons et al. (1994) called this organization the mode 1 of research. This mode describes the CGIAR in its early days, except that instead of just one institution, the centers coordinated breeding networks. In mode 2, teams are multidisciplinary, multi-institutional (often involving researchers from the public and private sectors), increasingly distributed in distant locations and relatively ephemeral, as they are formed to respond to specific issues. This organization allows innovative agents and research institutions to react rapidly to emerging technological needs or opportunities. How to switch to mode 2 is the most important challenge the CGIAR faces today.

5. A review of the CGIAR

The original design of the CGIAR reflected the success of the Green Revolution, the fact that most of the poor lived off of agriculture (see section 2) and a linear vision of science. In its early years, the CGIAR had a very clear and narrow goal: to stave off hunger by increasing the

productivity of staples in small farms (Alston, Dehmer and Pardey 2006). Thus, it gave highest priority to breeding improved varieties of cereals. In the 1970s, about two-thirds of CGIAR resources were allocated to research on rice, wheat and maize. High priority was later given to improving the quality of diets through research on food legumes and ruminant livestock (Anderson 1998). The initial success of the CGIAR resulted from the collective effort of high quality researchers working on a narrowly focused problem (i.e., plant breeding) and policymakers providing the economic incentives to induce adoption (Morris and Byerlee 1998). In this sense, the CGIAR in its early days repeated the formula that made the US research system highly effective (Kraemer 2006) and was similar to other successful programs, such as SEMATECH.

Following the linear vision, the first CGIAR centers were the central nodes of breeding networks that included the NARIs selecting locally adapted varieties, extension services taking the seeds to the farmers and sometimes policy makers providing the economic incentives to induce adoption. The limited impact of improved germplasm on poverty outside South Asia soon became apparent, and in 1971 the donors and centers expanded their activities under six broad program thrusts: research to increase productivity of food production; management of natural resources; assisting countries in designing and implementing food, agricultural and research policies; capacity building by training and strengthening national agricultural research systems (NARs); germplasm conservation by collecting and classifying genetic resources and maintaining genebanks and other means of conservation; and building linkages between NARs and other components of the international agricultural research system (Anderson 1998).

The new activities were added with little consideration for what these changes meant for the type of science the CGIAR should conduct. Several factors reduced the effectiveness of the

expanded mandate. First, in contrast with the focused mission of the first years, the new objectives were more diffused and spread the resources over more activities. Second, breeding is essentially different from research in other agricultural fields. Breeding relied on networks that fostered international exchanges of germplasm; in other words, they increased diversity combined with an effective selection mechanism; in this way they helped to identify the most promising varieties. The other activities did not form similar global networks and worked with a smaller set of partners because their research was more location-specific, and no agreement emerged on what were the best methods to study those topics. Additionally, it was not clear what advantage international researchers had in more location-specific research (CGIAR 2006).

Third, seeds of some commercial crops (e.g., maize and wheat) are probably the only embedded technologies where public and private agricultural researchers “compete”. Most other embedded technologies (e.g., agrochemicals and machinery) are generated by private firms, while public research develops disembodied technologies, i.e., information that farmers have to “absorb” to improve their productive packages. In the 1990s donors started to question the effectiveness of agricultural research when it became clear that the CGIAR centers were not participating in the most dynamic agricultural markets (see section 2) and their impact on poverty was not evident. Initially, success of breeding programs was measured by the number of varieties released, while adoption was the benchmark for other agronomic research. When adoption also became a benchmark for breeding, many stakeholders started to question the system’s effectiveness. Fourth, while the centers could often find good partners for breeding in some NARIs, it was more difficult to find them in other research areas.

In the 1980s and 1990s, the conceptual model of research systems in developing countries underwent major changes. The concept of the NARIs was replaced by the NARS, which also

included universities and other agricultural research institutions; later the NARS was replaced by the AKIS which included research, education and extension (Byerlee, Alex and Echeverria 2002). While these models still reflected the linear vision of science, they showed that the CGIAR had to develop new interactions with a more diverse set of partners, many of which had weak research capabilities (see, for example, Spielman et al. 2008).

Several stakeholders criticized the NARS for their lack of participation in the emergence of high-value markets and the failure of modern varieties to eradicate poverty. This led to a substantial downsizing or closure of public research and extension institutions (Byerlee, Alex and Echeverria 2002). The CGIAR centers found that they could no longer rely exclusively on weakened traditional partners, and started to work with private firms and NGOs. But these interactions were in general more local than crop improvement.

In these years, the CGIAR's mandate expanded even more. The new activities included managing research networks to facilitate research performed by others, some in conjunction with CGIAR centers (Plucknett, Smith, and Özgediz 1990); rehabilitating seed stocks in nature- or war-ravaged countries; promoting no-till, and developing niche markets. Because the expanded mandate had to be met with reduced budgets, breeding programs were further scaled back (Alston, Dehmer and Pardey 2006). The expansion in the number and types of potential partners the centers could work with made most of their networks even more diffused and required developing new types of capabilities and interactions. Some of these activities have been branded "development less directly related to research" (Alston Dehmer and Pardey 2006, pp. 324). It should be noted, though, that this statement reflects a mode 1 research; if properly conducted, these activities could involve action-research methods and fall into the mode 2 type.

After realizing the potential of high value agriculture to eliminate poverty, several centers started to work on diversification and development of niche markets to the point that high value agriculture has become one of the CGIAR's priorities (CGIAR 2005). This type of work, however, differs greatly from that done on staples and livestock. Because high value markets are more complex, newer and fast changing, development of the business model is, at least, as important as the agronomic package (Reardon 2005). When their mandate committed them to work in low value products (e.g., maize or rice), some centers explored the use of their crops as inputs in the production of high value products. But the CGIAR centers did not have the expertise to develop agricultural value chains. Over time, a few centers (e.g., CIP and CIAT) developed some of these capabilities, but, then, they became more similar to some NGOs and increasingly different from traditional research centers. This does not mean that these activities should not be done, but it is not clear what advantage the CGIAR has in this area relative to specialized NGOs (e.g., Technoserve) or universities with strong international programs such as MSU or Wageningen.

The main challenge agricultural research in the CGIAR now faces is that the networks it formed in the past are no longer viable because most NARIs have weakened, and the new partnerships that need to be created require new models of science, new partners and new patterns of interaction. However, because of the complexity of innovation processes and the rapid changes science is going through, there are no clear guidelines for how to build these partnerships. Complexity theories and the innovations systems framework can provide guidance on how to approach the problem (see below and section 7).

Social science (including economics) always played a subordinate role in the system. Initially, these programs were created to study the factors that determined farmers' adoption of

improved varieties (Cernea 2006). When funding declined in the late 1980s, the priority shifted to measuring the centers' impact to justify their work to the donors. In recent years, several centers have started programs to analyze the nature of agricultural innovations, but these efforts are dispersed and have not reached critical mass (e.g., CIP, IFPRI and ILRI). In addition, learning how to promote innovation among small farmers requires new research routines (Ekboir et al. 2008), and few centers have developed expertise in them.

The CGIAR's two specialized social sciences centers (ISNAR and IFPRI) require special consideration. ISNAR was mandated with helping NARS; when these were downsized, donors started to question their support to a center meant to work with institutions that were neglected by their own governments. Recognizing the new environment, ISNAR started to explore the concept of innovation systems; this new direction, however, was strongly criticized by the Technical Advisory Committee and the External Program and Management Review, and contributed to its closure (ISNAR 2002).⁶

This criticism, however, reflected the linear vision of science, and a lack of understanding of the emerging needs of innovation networks in developing countries. While the NARS weakened, the importance of other actors in the innovation system increased (see sections 2 and 3). These actors, the international centers and the CGIAR included, also needed support to strengthen their capabilities to manage innovation processes and to develop instruments appropriate for the new economic and social environment, in particular innovation policies. Most organizations, however, have great difficulties in developing new capabilities on their own (Christensen and Raynor 2003; Smit 2007). To overcome these hurdles, the specialized literature

⁶ It must be also recognized that serious management problems contributed to ISNAR's closure (ISNAR 2002).

recommends creating bridging structures that help organizations find useful information, mediate between researchers and other areas of the network and identify internal and external barriers to innovation (Davila, Epstein and Shelton 2006). ISNAR was starting to work along these lines when it was closed.

Recently, some donors (e.g., DFID and CIRAD) and centers (e.g., Bioversity) started to explore programs to develop innovation capabilities (see, for example, DFID's Research into Use program and Bioversity's ILAC initiative), but these efforts are isolated. Because of its large and diverse international network, the CGIAR could play a bridging role in innovation networks, and help NARIs to adapt to the new vision of science (see below).

IFPRI was created to research food policies and provide policy advice. From its beginnings, it developed a culture that valued publications in scholarly journals above more applied work and interactions with policymakers in developing countries. Because many contained policy lessons applicable to several countries, these studies were branded as international public goods, but they are no different from many papers published by researchers from other international organizations, think tanks or universities. For most of its life, IFPRI established weak links with other CGIAR centers and policymakers in developing countries and could have been a department in a good university. While in recent years IFPRI has introduced new programs with input from social sciences other than economics, the center still has an academic culture that does not fit into the new paradigms of science (see section 4).

Additionally, IFPRI's culture resulted in an extremely narrow exploration of policy alternatives, overreliance on a restricted theoretical body (i.e., essentially microeconomic theory and quantitative methods) and, sometimes, policy advice of dubious quality. For example, its research policy recommendations have not evolved in the last twenty years (see, for example,

Alston, Dehmer and Pardey 2006), and are based on the linear vision of science, and mechanistic models (e.g., DREAM and ASTI). In other cases, the policy recommendations are based on uncorroborated assumptions without checking their validity. For example, Ruben and Pender (2004) assert the existence of diminishing returns to investments in research. The empirical evidence on diminishing returns, however, is far from conclusive. Diminishing returns are assumed in static microeconomic models in order to derive an analytical solution; quantitative analyses that do not find decreasing returns are generally considered flawed and discarded. In dynamic, complex models, however, there is no reason to assume diminishing returns. Because the interaction between positive and negative feedback loops is continuous and changing, returns can alternatively be increasing and decreasing. In short, decreasing returns are the result of the assumptions used and not necessarily happen in reality. Although IFPRI broadened the scope of its research in recent years, it is still dominated by a culture that does not value interaction with non-academic stakeholders and experimentation of new research methods. This culture partially explains the failure of the ISNAR division.⁷

In 2003 the CGIAR launched the first Challenge program; a new approach to building partnerships that could have major implications for the system. These programs provide a flexible mechanism to structure multidisciplinary, inter-institutional teams to address specific issues. If properly managed, they provide the basis for conducting mode 2 research (see section 4).

Two reviews by the Science Council and the CGIAR Secretariat (Science Council 2007 and 2004), however, indicate that the CGIAR still evaluates the Challenge Programs from the

⁷ Serious management mistakes also contributed to the failure.

narrow perspective of the linear vision of science. The rationale for the Challenge programs should not be the generation of international public goods (in other words, information), but the exploration of new institutional arrangements through which formal research can contribute to poverty alleviation, and to build innovative capabilities in developing countries. These instruments should not necessarily include the international centers, or could be outside their areas of expertise. The CGIAR, however, can use its international scope to manage and supervise these programs and to transform them into effective learning mechanisms. Several donors already fund some activities of this kind, for example, DFID's Research into Use program, but they remain isolated activities.

In 2004 the Science Council was given more power to oversee the work of the centers, especially, setting the system's priorities (CGIAR 2005). Since then it has been trying to align the centers' activities with these priorities. Such alignment can have serious consequences. As was explained in section 3.1, complex processes are difficult to understand and predict. Therefore, instead of setting clearly defined strategies and priorities, actors operating in such environments should use strategies for identifying emerging trends and exploring alternative solutions. Fifteen independent but coordinated centers can be a very effective structure to implement a strategy of decentralized experimentation with centralized learning. In fact, most centers have already implemented innovative projects in response to identified opportunities; what the system lacks is an effective and flexible structure to learn from these projects. The Science Council could become the basis of such structure and help to identify new research needs, opportunities and methods where the CGIAR can make a contribution.

An additional problem is that the model of research behind the priorities set by the Science Council still reflects a linear vision of science (see Science Council 2005). Forcing the centers to revert to such model would isolate them even more from innovation networks.

6. What role should the CGIAR play in poverty alleviation?

The new dynamics of rural poverty and the better understanding of science and of its role in development have two major implications for the CGIAR. First, the CGIAR has been justified as a source of international public goods (Alston et al. 2006; Science Council 2005). The public good the CGIAR produces is scientific information, either embedded in seeds or disembodied as papers and recommendations.⁸ As was explained in section 3.3, however, the contribution of scientific and other information to innovation (and poverty alleviation) depends on the innovators' absorptive capabilities, including their ability to access and use information generated in distant locations. Therefore, the system's impact depends, among other factors, on the quality of its research, the relevance of the information to innovators and their ability to use it. In other words, the CGIAR must adapt its current activities to interact more effectively with researchers and with other actors in innovation networks. The communication must be two-way. Researchers need to understand the innovators' needs and the dynamics of poverty, and the innovators need to be able to find and use useful scientific information. The weakening of public research systems in developing countries and the increasing importance of the private sector and civil society organizations in developing countries are adding urgency to the establishment of these links. But this work is less "upstream" research as required by the Science Council and

⁸ The CGIAR also conducts other activities that are not public goods.

more “development”, and requires a redefinition of the CGIAR activities, in particular, of its social scientists (see below).

Second, the CGIAR’s contribution to poverty alleviation depends on the creation of effective learning routines to explore more effective interventions to foster innovation. Such learning routines must be developed both by the innovation networks and the CGIAR itself. Because of its global presence, the CGIAR can help to identify successful experiences in many countries, link innovators with sources of scientific and technical information (including advanced research institutions) in distant locations and use action-research to help adapt foreign experiences to local conditions. In this way, the CGIAR would become the central node of a system of decentralized experimentation with centralized learning. An example of such work was the development of a no-till planter for small farmers involving actors in Bolivia and India, process in which CIMMYT played a key role (Ekboir 2002).

The exploration should also include the traditional breeding networks, but including new partners. Sixty years ago, these networks were centered in the CGIAR, and included public and private breeding programs, seed companies and extension services. Today, the public actors in developing countries have seriously weakened, leaving the CGIAR without its main partners. While new partnerships are emerging, the CGIAR should explore more actively additional arrangements to better support the diffusion of improved seeds.

Similarly, the CGIAR should use its decentralized structure to adapt faster to emerging needs and opportunities. Such adaptation requires experimentation and flexibility, but the CGIAR is not currently a learning organization. With its current vision of science and organization, the system is too rigid and atomized to learn from the activities of the individual centers. To become more nimble, the CGIAR should:

- Realize that innovation is a complex process that depends on the emergence of networks with different types of partners; even more, the networks' composition and governance must respond to the unique needs of each process. The CGIAR can catalyze the emergence of such networks. In fact, this is already being done in the Challenge programs but these should be expanded and given more flexibility as was explained in section 5. Such changes run contrary to the recommendations issued by the CGIAR secretariat and the Science Council (Science Council 2007 and 2004).
- Recognize that unforeseen problems and opportunities will emerge. Rigid priority setting would miss these emerging issues and reduce the system's impact. Additionally, individual institutions (including the CGIAR centers) cannot change fast enough to address emergent issues, but a diversified, large global system can (Kramer 2006). In other words, the CGIAR should tap more into good researchers from a wide range of institutions that manage programs that may not involve staples. The key for such strategy is to have a strong executive office to identify the problems, identify actors (including researchers) that can develop solutions and allocate the resources. Such strategy would require strengthening the Science Council and changing its function from overseeing the centers to fostering learning through experimentation.
- Reevaluate the role of social research in the CGIAR. Many centers do not have a critical mass of social scientists; even more, the number of scientists has been falling and they were never fully integrated into the centers core activities (Cerenea 2006). In addition, it is not clear what IFPRI is doing that could not be done by universities with strong international programs. Other centers have been more innovative in searching for new paths to foster innovation, but again, it is not clear what advantage they have over specialized organizations

like PROLINNOVA or KIT at the Royal Tropical Institute, Amsterdam. As was mentioned in section 5, these organizations do not have effective learning routines, which opens a niche for the CGIAR. Social scientists from all centers could strengthen their collaborations to achieve critical mass for the creation of a learning structure to explore new ways to a) foster the emergence of innovation networks that involve ARIs and developing countries teams and identify the roles the international centers should play in them, b) promote institutional change in their centers, c) help the centers' researchers from other disciplines to develop new research modes that facilitate interactions with other actors; and d) given the failure of traditional training programs to build lasting capabilities in the public sector, build the capabilities of other actors in innovation systems. IFPRI's ISNAR division could have been the core of such "virtual" social sciences center, but currently lacks the capabilities and incentives to do it.

- Better understand the joint dynamics of agricultural production, globalization and migration to redefine the CGIAR's role in poverty alleviation. In particular, it should explore the different pathways poor rural households can follow to escape poverty, what capabilities these households need to follow the different paths and what instruments can be implemented to build these capabilities. It should also explore the role traditional research (including breeding) should play in these processes.

7. Final remarks

The dynamics of development and poverty are rapidly changing due to globalization, migration and technical change. In the last two decades, many poor rural households have diversified their livelihood strategies, seeking more off-farm income and high value agriculture at the expense of low value products. Most of the technologies used in high value agriculture

were developed by private firms and distributed by the private sector or NGOs; public research institutions and extension had very limited participation in the most dynamic markets. Additionally, several studies have found that growth is the most effective way to reduce poverty, which questions the strategy of supporting low value agriculture by small farmers as a development instrument.

These facts are starting to change the perception of the effectiveness of traditional development policies, including the role agricultural research should play in poverty alleviation. In particular, the concept of innovation is replacing the traditional research and extension continuum. Innovations are developed by networks that include private firms, farmers, technical advisers and, in some cases, researchers; in fact, most innovations do not originate in formal research but in productive or social processes. The networks' ability to innovate depends, among other factors, on their absorptive capabilities, i.e., their ability to search for and use existing information, whether it is scientific, commercial or organizational.

The innovation systems framework questions the traditional role assigned to the CGIAR, i.e., the production of international public goods. The information generated by the international research centers can only be used by those actors that have invested to build their absorptive capabilities. In other words, while the information is free, its use is not. This observation helps to explain the limited expansion of agriculture in poor households despite the fact that many of them receive remittances from migrants.

The CGIAR defines itself not just as a technical but rather as a development research institution (Cernea 2006). To fulfill this vision, the system will have to adapt to the new environment, facilitating the interaction between global research and local innovation networks,

and helping innovation networks to access technical information and to create it when it is lacking, in other words, strengthening its role as a bridging agent.

It will also have to add flexibility to its centers, so that they can explore new instruments to foster innovation. This will require a redesign of the Science Council so that instead of an organ of control it becomes a key agent in a learning structure.

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