New Agendas for Agricultural Research in Developing Countries: Policy Analysis and Institutional Implications

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This article argues that the goals of agricultural research in poor countries have changed substantially over the last four decades. In particular they have broadened from the early (and narrow) emphasis on food production to a much wider agenda that includes poverty alleviation, environmental degradation, and social inclusion. Conversely, agricultural research systems have proved remarkably resistant to the concomitant need for changes in research focus. As a result many, at both the national and international level, are under great strain. In terms of public policy the article goes on to suggest that shortcomings of existing conceptual approaches to technology development could be supplemented by adopting analytical principles that view innovation in systemic terms. An approach where flows of knowledge between institutional nodes is a key to innovative performance (the "National Systems of Innovation" approach) is suggested as one such conceptual framework that might help supplement conventional policy analysis.

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Introduction

Over the last four decades agricultural research has been a major policy tool in efforts to alleviate poverty in developing countries. Initially, this was couched in terms of reducing food poverty. However, as the political economy of donor assistance and national public policy has evolved, so too have the policy goals of agricultural research. The goal of producing more food rapidly shifted to increasing the productivity of the rural sector; the assumption being that sustained rates of economic growth would lower instances of both rural and urban poverty. Latterly, protecting the natural resource environment has been added to the tasks that agricultural research must achieve. Most recently, agricultural research has been asked to re-examine and enhance its impact on a much more broadly defined concept of poverty and the factors that cause it.[1]

Such changes in policy goals quite rightly reflect our growing understanding of the nature and causes of poverty and the complexities of the linkage between new technology, economic growth, and poverty reduction. They also reflect the influence of an increasingly diverse set of interest groups on both international and national public policy arenas. As a result public sector agricultural research systems in developing countries are finding their contribution to national welfare under growing scrutiny. Equally, the Consultative Group on International Agricultural Research (CGIAR) centers of the international agricultural research system are under greater pressures from the donors to make their impact more tangible and explicit. All too frequently agricultural research systems are stereotyped as inefficient, centralized, bureaucratic hierarchies, unaccountable either to their mandated clients (poor farmers) or to their public sponsors. What has focused attention on agricultural research in this way? Why do the traditional models of agricultural research systems seem so at odds with the complex agendas of recent public policy in national and international arenas? And how can we deal with this from a policy perspective?

We believe that the answer to the first two of these questions concerns four related factors:

1. The historical development of agricultural research systems, in particular the political and ideological context in the crucial formative years and the conceptual position concerning innovation suggested by the institutional provisions put in place at that time.
2. The evolution of the policy context, partially as a result of early success and lessons learnt from green revolution (GR) technology, but also due to the emergence of a much more inclusive understanding of the development process.
3. Radical changes in the wider global economy, which have *inter alia* led to fundamental ideological changes concerning the proper role of the State in contemporary society.
4. The difficulties that agricultural research systems have had in evolving institutional structures to match the new tasks that the changing policy agenda seem to dictate.

Put another way, our argument is that both national and international agricultural research systems were established at a time when expectations concerning the performance of the research process were fairly straightforward. At the risk of over-simplification, the green revolution was concerned with increasing the productivity of agriculture in order to increase the aggregate food supply. This was seen as a way of reducing hunger and the poverty associated with it. The institutional arrangements to achieve this goal were consistent with prevailing ideas concerning the organization of science and its relationship with innovation and economic production; namely that centralized scientific research institutes could solve the generic problem of increasing the biological potential of important food crops and that this would lead to increased food production. The task to be achieved was conceptually quite simple and all the actors in the system charged with achieving it held a similar clarity of purpose. However, as the policy agenda has moved away from articulation in broadly scientific terms to one articulated in more developmental terms, existing research structures have had increasing difficulty making satisfactory contributions.

Our concern here is that while new policy agendas are asking agricultural research to deal with a phenomenon that is now recognized as vastly more complex than originally presumed, our conceptual position concerning the creation of new knowledge as a developmental tool has changed very little. As a result, rather simplistic assumptions concerning the linearity of relationships between public investments in the creation of new technology and poverty reduction are still widespread and these continue to dominate institutional models. Rather paradoxically, contemporary policy analysis of innovation in the context of industrialized economies has increasingly come to rely on an approach that deals precisely with these types of complexity, particularly the institutional dimension. Often referred to as the "national systems of innovation" (NSI) approach, this school of policy analysis views innovation in systemic terms, where the "connectivity" of organizations is key. The application of the NSI approach in policy formulation in developing country agricultural research is broadly untested. This article presents the broad principles of NSI as an alternative conceptual framework and suggests ways it can be applied to the task of restructuring agricultural research systems to improve the efficiency of fulfilling policy agendas such as poverty.

The article begins by reviewing the origins of the national and international agricultural research systems. We trace the way the political and ideological context of the time shaped early institutional development. We go on to demonstrate the way the evolving policy agenda has made institutional arrangements of critical importance, before outlining alternative ways of addressing the problem. Clearly, there will be difficulty involved in changing institutional structures. But, nevertheless, in conclusion it is safe to argue that such changes, while experimental, will need to take place if agricultural R&D is to continue to play a positive role in solving the complex issues that we are faced with in the new millennium.

The Origins of National Agricultural Systems (NARS)

In most developing countries the origins of the NARS can be traced to the pre-independence era. Often (although not always) this initial period of institutional development was to support the production of major agricultural exports. Good examples are the cotton and coffee research institutes found in East Africa. Scientifically validated improved practices were developed for application in the commercial agricultural sector, a production context conveniently similar to the trial plots of experimental stations. In the post-independence period attention began to focus on much wider needs, particularly the problem of increasing food production to supply rapidly growing populations. The general pattern that emerged was one of widespread public investment in agricultural research systems (often with external assistance). Being conceived and designed with scientific research in mind these systems evolved into a matrix of commodity and disciplinarily segregated institutions. They were also invariably linked to some form of public sector extension system to facilitate the transfer of new technology to farmers. Agricultural universities (or dedicated university departments) also formed part of this system, often carrying out both a training and research function.

To illustrate what this meant in practice the Indian experience provides a useful example. India has had a particularly interesting history of institutional development with its NARS comprising a national level research council (the Indian Council for Agricultural Research [ICAR]), a wide range of research organizations and a state level agricultural university system. At independence an already extensive (for the time) agricultural research infrastructure existed. This developed into ICAR, which consisted of a range of national level research, institutes undertaking basic and adaptive research as well as postgraduate training. International concerns in the late 1950s and early 1960s over the need to dramatically increase food production led to the financing of a number of additional research institutions. These were based on the U.S. Federal State system (the Land Grant System) and were initially supported through the Ford Foundation and bilateral aid, and later with multilateral aid (de Janvry and Dethier, 1985). This led in the early 1960s to the creation of India's State Agricultural Universities with a combined function of agricultural education, adaptive research and extension.

This period of institutional development in India also coincided with post-independence moves towards self-sufficiency. As already seen, self-sufficiency in food was to a large degree the rationale for strengthening agricultural research. However, India was not just concerned with self-sufficiency in terms of food (or even indeed, manufactured goods). It was also concerned with self-sufficiency in terms of the science and technology capability to support such a self-reliant development trajectory and the economic independence that this brought with it. This was part of the post

independence (Nehru's) vision of "modernizing" India and the creation of the vast scientific infrastructure felt necessary to achieve this. It was also coupled with the prevailing ideology of socialist leaning post-independent India in which the State sought to develop and directly administer all the major components of the economy. The public investment from this early period is still seen today in India's agricultural research system. ICAR remains one of the most institutionally numerous and diverse NARS in the world. Furthermore, it is a system that continues to broadly rely on the guidance of scientific priorities that stood it in such good stead during its early years. Although not all developing country NARS are as large as in India the broad design principles were similar.

The Origins of the International System

During the 1950s, international worries concerning the potentially destabilizing effects of rapid population growth and inadequate food supplies in East Asia led donor organizations like the Rockefeller and Ford Foundations to move their focus from health to agriculture. Some of this support was channeled towards developing national agricultural research facilities. However, concerns over the level of national investment in research systems and therefore the ability of these systems to solve the problem of food supply led to the creation of international agricultural research centres to backstop national efforts. The early pioneers were the International Wheat and Maize Improvement Centre (CIMMYT in its Spanish acronym) in Mexico and the International Rice Research Institute (IRRI) in the Philippines. These formed the basis of what became the loose association of sixteen or so international agricultural research institutes managed by the Consultative Group for International Agricultural Research (CGIAR)[2], often referred to as the CG system

To a very large degree the establishment of the early CG centers reflected the prevailing political and ideological context of the time.[3] Anderson's (1991) discussion of the establishment of the IRRI usefully demonstrates this. The origins of IRRI (and CIMMYT) stemmed from the funding of agricultural research by the Rockefeller Foundation and later the Ford Foundation. It was closely associated with an America foreign policy that saw that food security problems, particularly in Asia, could lead to political instability and the spread of communism. The Rockefeller Foundations took the decision that the drive to increase food supply should be "technology-led" with yield per hectare as the key dependent variable. Complex issues associated with farmer size, access to inputs, applicability and socio-economic relevance were placed to one side in order to focus thinking and resources on the one key objective, transforming agricultural productivity by means of improved germplasm. The focus was on so called *isolable* technical problems[4]—*isolable* in the sense that they could be isolated from the socio-economic context of farmers and the political context of target countries. This dictated to large degree the central strategy of the early CG centres. The strategy was science-led, with mission success depending on

narrow goal specification combined with rigid adherence to the best technological means of achieving the goal as quickly as possible.

Over the years the CG system has grown to some sixteen centers. The mandates of the centers have broadened from an initial focus on commodities to include eco-regionally focused centers. The guiding principles were, however, broadly the same, namely a scientific agenda of increasing the productivity of the biological systems that underpin developing world agriculture. Only in the very recent past have moves been made to examine institutional ways of embedding the scientific agenda in a more developmental context.

Conceptual Position

This pattern of institutional development underpins much of the public sector agricultural research system that we see in the developing world today; namely a loose association of international agricultural research institutes supporting to various degrees, sets of commodity and or disciplinary based public sector research institutes at the national level. Responsibility for technology transfer normally rests with a cash-starved public sector extension system. Established as scientific research organizations with clear technical goals (in the early years) these institutional arrangements reflect the scientific method of reducing problems to fundamental components; in this case poverty viewed as food availability, that in turn is to be tackled through yield enhancement on a commodity and disciplinary basis.

We believe that this pattern of institutional development reflects a tacit endorsement of a linear model of innovation, a model in which investments made in basic research produce knowledge whose value increases through further "downstream" incremental investments in adaptive research. The knowledge is finally given to a dedicated organization charged with passing it to technology users (farmers in this case) who finally apply the new knowledge to economic production. This model is often referred to as the "pipeline model," resources entering at one end of the pipeline and economically useful knowledge leaving at the other.[5] There is also institutional separation, with activities associated with knowledge search and generation organized separately from those involved with knowledge transfer and application. There is thus a division of labor whereby scientific bodies are conventionally organized into a hierarchy of institutional structures with a linear flow of resources and information from the top to the bottom.

We shall return in latter sections to a more in-depth discussion of the implications this has had for agricultural research. However, as Biggs (1980, 1985, 1989, 1990) and many others have pointed out, there are a number of important implications that result from this model. These include the difficulties found in incorporating client feedback into research priorities; a lack of accountability to client groups; a tendency for scientific excellence to dominate over the achievement of developmental goals; and a tendency for policy analysts (usually economists) to concentrate exclusively on the

impacts of technologies coming out of the pipeline, often in comparison with investment of resources at the inward end. These points help inform our discussion in the next section.

The Early Successes and New Problems

Increased Production

In fact the science-based agendas of the national and international agricultural research systems exhibited some outstanding successes in the early years. The application of crop improvement principles—notably dwarfing, hybrid vigour and fertilizer responsiveness—to the cereal crops of the developing world (rice, wheat, and maize) created a series of high yielding varieties (HYVs). Collectively, these new varieties underpinned the phenomenon that came to be commonly referred to as the green revolution (GR). For example following the release of high yielding rice variety IR8 India in the mid-1960s almost 60 percent of all rice produce was of the HYV type a decade later. Results for wheat were even more impressive, with over 80 percent produced as HYVs by the mid-1980s. Maize and sorghum HYV adoption was less dramatic, but still increased to over 30 percent of the total in the same time period. Yield increases were even more spectacular, sometimes producing double the yield of traditional varieties.[8]

Increasing Concerns

Judged in terms of increasing productivity and food supply therefore—the policy agenda for which research systems were established—agricultural research was clearly succeeding. However, the success of the strategy in a sense revealed that performance criteria for agricultural research needed to change. Starting in the early 1970s, social commentators (notably Brown, 1970; Griffin 1974) began to question the validity of the HYV strategy. It became apparent that increased agricultural productivity and food supply *per se* was no longer enough to eliminate poverty. This is not to argue that increasing agricultural productivity did not reduce poverty. It did and will continue to do so but, although necessary, it is not on its own sufficient to combat poverty. As a performance criterion alone productivity was no longer a sufficiently useful measure of the ability of the research system to stimulate agricultural innovations that met the demands of society as a whole.

It was not just that more food was not tackling poverty as quickly as initially presumed, but that the strategy was not actually addressing the production needs of vast number of the poorest farmers. It was this inability of research systems to address the needs of client groups—and the inevitable questions of social neutrality that this led to—that has become one of the most enduring criticisms. Lipton and Longhurst (1989), in their definitive review of the GR, even dismiss the term "revolutionary." They suggest that its use reflected a perception of scientists during the late 1960s that

HYVs could produce "revolutionary" improvements in the well being of the poor without political upheavals (the fear of which had led to international investment in improving food production). In fact, Lipton and Longhurst argue that despite the widespread adoption of HYVs, particularly in Asia, the poor were neither numerically smaller nor less socially impoverished, absolutely or relatively, compared to the groups that held power before HYV introduction. The biological potential of cereals was certainly revolutionised, but this was not associated with *revolutionary social change* that would banish poverty forever, or even decrease it proportionately to the yield increases achieved.

The reasons why increases in food supply did not have concomitantly large impacts on rural and urban poverty are complex and still hotly debated. Detailed discussion of the ultimate impact of the green revolution is beyond the scope of this article.[7] However, key issues include the following:

- The poor benefited directly if they had land, water and other resources allowing them to adopt HYVs. However, frequently they did not.
- Attention to matching factor-consuming characteristics of HYV technology with the resources of the poor *could* increase adoption and poverty impacts. But it was a critical failure of such research that it was often not responsive to client needs.
- For most of the poor in Asia and Latin America (both rural and urban) benefits needed to come from cheaper food supplies. However, extra food output and availability is only useful to the poor if they have access or "entitlements" to it (Sen, 1981, 1986). In the case of the landless and the urban poor this needs to be through employment income.
- In fact cheaper urban food prices are often (although not always) passed on to employers rather than poor employees, due to the impact low prices combined with surplus labour can have on wage rates. In the rural sector, increased labor demands of the HYVs often led to the adoption of labor saving technologies.

Science vs Development

What this type of analysis means is that by the mid-1980s there were fairly clear messages coming from a large body of debate suggesting that reducing poverty through agricultural research was far more complex than initially envisaged. Retrospectively, the all too clear lesson was that if agricultural science was to make a contribution to poverty, it needed to operate in a developmental framework rather than a scientific one. And such a developmental framework should deal with poverty not in terms of changes in food supply and availability alone, but in terms of the complex social and economic factors that underpinned it. A key element of this was the need for agricultural research to adopt a client-responsive *modus operandi*.

In actual fact much of the of the early social science debate focused on the factor-consuming characteristics of technology, (often with recommendations for re-prioritization of scientific agendas). However, in the main it

did not question the ability of agricultural research arrangements to capture and account for these factors (Hall et al., 1999). In other words there was no engagement with the more fundamental issue of the way the R&D process (and the institutional arrangements that shaped it) was affecting the success of the technical solutions it was producing. We discuss this in more detail later, but first it is necessary to look at the emergence of further new agendas that are related to issues of a more global nature, and the way this finally made the institutional question inescapable.

Expansion of the Agenda

Environment

It was not only issues of the political economy of green revolution technology that were being debated. There was also a growing realization of the environment consequences of an intensive agricultural development strategy reliant on chemical inputs and heavy consumption of water from environmentally damaging sources; the salinity effects of large-scale use of ground water were highlighted in particular. This coincided with the growing global awareness of the potential long-term consequences of environmentally damaging development models.[8] Agricultural development associated with the HYVs was not particularly worse than any other "modern" technology in other sectors at this time, but its prominent profile and detailed scrutiny tended to highlight the problem in the eyes of the public.

More generally, the profile of the environmental issues in development was initially raised in the early 1970s as a result of the Stockholm Conference on the Human Environment in 1972 and the resultant foundation of UNEP in 1974. This was followed by the influential Brundtland Report (WCED, 1987) and the UNCED "Earth Summit" in Rio in 1992. Other important statements on the topic have been made by influential bodies such as the IUCN, FAO, WWF & WRI and by a growing number of academics.[9] The 1980s also saw the establishment of an increasing number of NGO environmental activist groups some with a specific focus on development. The writings of these groups have helped to raise public awareness of environmental issues.[10] By the early 1990s, therefore, environmental issues were firmly part of main stream public policy agenda, and this was reinforced by a number of high profile UN conferences held at the time (Echeverria, 1998).

Environmental considerations, sometime couched in terms of sustainability, are now firmly part of the development agenda and resultant policies are impinging directly on agricultural research. Consequences include the "conditional" requirements on the part of many international donors for *ex-ante* assessment of environmental impacts. Institutional dimensions have been raised by the consequent shift in emphasis to environmentally benign technologies, particularly natural resource management and integrated pest management. Implicit in these approaches has been the shift in emphasis from technological solutions to management solu-

tions, usually management by farmers themselves. This still includes a technical component or underpinning. However, of increasing importance are issues of social organization to manage shared resources and the subsequent need for research working practices that involve much closer interaction with client groups. It has also meant that research groups wishing to succeed in these new approaches have had to establish collaborative relationship with organizations that can engage farmers more directly–usually NGOs.[11] It is all too easy therefore, to see how this change in approach often 'sits uncomfortably with more traditional concepts of agricultural science professionalism. However, as we now go to show there is growing policy pressure to work more closely with client groups.

Participation

It is important to note that while earlier criticisms of agricultural research performance concerned the appropriateness of the new varieties and technology in terms of their suitability for poor farmers, this criticism left the agricultural research system largely blameless. That is application questions were assumed to be "exogenous" to the technology/poverty equation. However, during the 1980s increasing criticism emerged of this (institutional) model of agricultural research, including the role of the CG centers. Biggs, in particular, drew attention to the key institutional dimension of the problem and specifically the hierarchies inherent in agricultural research systems fashioned on the linear model of innovation that we have already discussed.

The essence of the critique was that the hierarchical institutional arrangements typical of most centralized agricultural research systems are unable to deal with the complex technology needs of farmers, particularly small farmers (Biggs and Clay, 1981; Chambers and Jiggins, 1987a,b; Biggs 1990). In actual fact the critique suggests that innovations are produced not by organised science alone, but by a number of actors including farmers, often in combination with other elements of the system. It also suggests that institutional arrangements embodied in the centralized science model of innovation, separate scientists and farmers to such an extent that productive relations are not established and that this is detrimental to the R&D process as a whole (Biggs and Clay, 1981).

The issues in the broader debate concerning the role of farmers in the research process have found expression in the farmer participatory research (FPR) movement.[12] Widespread support for these ideas has been spread by Chambers and other advocates, but as Bentley (1994) points out, despite the large volume of literature on FPR evidence of the success of technical innovation as a result is scarce. Farrington and Martin (1988) were among the first to point out that the FPR model raised many questions concerning the mechanisms by which linkages can be formed between farmers' own research activities and those of formal science. The FPR movement also appears to have been engulfed in a wider agenda of farmer empowerment. This seems to have detracted attention from the initially sound basis of trying to improve the

efficiency of the agricultural research by tackling underlying institutional constraints. As a result, participation has arguably become an ideological norm rather than the powerful policy tool that its early promise suggested.[13]

Leaving to one side for the moment the (continuing) debate of ability of these methods to deal with the maladies of agricultural research, one of the undisputed outcomes has been to place the participatory "paradigm" in the mainstream. As a result, during the last decade agricultural research systems have had to try and accommodate (with varying levels of enthusiasm and success) this new agenda in both research practice and research focus (see for example, Hall and Nahdy, 1999). However, all too often much of the advocacy for this change in approach has focused on participatory methods rather than underlying institutional issues.[14] Biggs and Smith (1998) argue that this "methods bias" masks the fact that the most successful participatory methods have arisen in specific institutional and political circumstances and have often evolved to deal with a specific problem area in that context. In addition, they have often been characterised by a significant degree of institutional innovation. Agricultural scientists all too frequently find themselves struggling to apply participatory approaches in an institutional and professional context that implicitly denies such patterns of interaction with clients (Hall and Nahdy, 1998). The contradictions and compromises that this has led to have neither necessarily contributed significantly to more farmer responsive technology nor helped maintain focus on the debate of the research process and its institutional arrangements.

Rolling Back the State

The participatory development "paradigm" has certainly provoked reflection on the need to devolve control of the development process to its clients. However, there is also a wider set of global changes taking place that has begun to focus directly on the core institutional issues. This change has been associated with shifts in globally held perceptions concerning the role of the state in society. Indeed, accompanying organizational changes at this level have increasingly come to dominate much of the basis of development policy and have made institutional concerns of fundamental importance. The origins of these global changes can probably be traced to the economic policies of the Thatcher and Reagan governments in the UK and the U.S. during the 1980s. In simplistic terms the approach was as far as possible to withdraw from direct state control of the economy, shifting emphasis away from state implementation to that of providing an appropriate (macro) policy environment. Central to this was the move to allow the market to provide services and to use competition to generate efficiencies that the public sector arguably could not achieve. The developing world first felt the consequences of the new ideology in the structural adjustment packages implemented by international financial institutions in the 1980s. The "adjustments" referred to macroeconomic and trade policy reforms (such as exchange rate reform, for example) but they also had to do with changes in the structure of the economy, mainly the extent to which the state pro-

vided public services and controlled key economic sectors. The approach was an attempt to reduce large and apparently unproductive, public sector bureaucracies, to break up state monopolies and to open up markets to competition, both nationally and internationally. As a result, the already embattled agricultural research systems began to face new challenges.

Not only did they need to focus on a much-expanded agenda, but also there was increasingly a more fundamental questioning of the nature of the role of the public sector in agricultural research. A key change that is making this all the more pertinent is the emergence of private sector research. This occurred partly as a result of improved intellectual property protection regimes and the technical advances associated with biotechnology. But also significant are the opportunities that economic and trade liberalization and globalization are now presenting for private investments in agro-industries such as seed production.

Complementary and Conflicting Agendas

The net result of this ever expanding range of new policy agendas is that the "one size fits all" type of agricultural research system no longer seems appropriate to this multitude of objectives. Often these new agendas actually conflict with traditional internally driven policies and beliefs of the research sector, particularly where these remain focused on production and productivity and continue to reflect the food security concerns of an earlier period (Roseboom and Rattan, 1998). Increasingly the difficulty concerns the integration of multiple sets of agendas, with national policy makers having to choose between serving, for example, the commercial needs of the agricultural sector while simultaneously serving the interests of society at large. In this way agricultural policy is no longer one-dimensional. It is faced with a far broader and more complex (and potentially conflicting) situation.

And these conflicts are all too abundant. Examples are the need to develop capacity in frontier areas of science, while also supporting adaptive research for traditional and subsistence sectors, the need to support, but not compete with, the private sector; the need to support the competitiveness of the private sector in global markets such as export horticulture, but not to displace small-scale producers; the need to achieve all of the above but without losing sight of the old agendas of increasing food production, without damaging the environment and without being socially divisive, and the need to contribute to poverty reduction without disadvantaging vulnerable groups such as women. And all of these goals need to be achieved in the face of ever shrinking financial support from the public purse.[15]

An Appropriate Policy Response?

The Institutional Dilemma

The way agricultural research systems have responded to these new policy agendas is limited and experimental (Clark, 2000). Institutional re-

form has taken place in a number of ways, with varying degrees of success.[19] Roseboom and Ruttan (1998) discuss the fairly adventurous sets of reforms that have taken place in the Netherlands. The rather promising institutional developments in Latin America (Echeverria, 1998) contrast with the more cautious approach in, for instance, India (Hall et al., 1998, 1999). And the CG system itself has been subject to a series of reviews in recent years with recent discussion suggesting the possibility of radical institutional change. However, of more importance to us here is how we start to deal with this issue from a more general policy perspective, particularly one that tackles the institutional dimension.

On the whole the evidence is that analysts are reluctant to grasp the nettle. Good examples of this can be found in Lipton (1988) and Pardey et al. (1997). Both of these try to explain declining expenditures on African agricultural R&D. In the latter the authors provide a detailed account of the decline in African agricultural research spending, but there is virtually no analysis of why this has happened. Consequently, the final conclusion, focusing on the need to increase finance, is unconvincing. The Lipton paper goes further in linking declining research expenditures to falling economic rates of return but the analysis virtually ignores institutional questions, concentrating instead on poor policy frameworks, below optimally sized research stations and product relevance. Similarly, Echeverria (1998) describes the way that, faced with uncertainties in a changing policy environment, agricultural research systems have often tried to justify their position in terms of returns to investment. For example, more rigorous priority setting exercises and ex-post impact assessments have been the primary response of many CG centers. But, in fact such measures have difficulty in judging returns to investment in terms of poverty, environmental protection etc., i.e., the new agendas. Equally, these approaches cannot account for the all-important "process" and institutional issues (Hall et al., 1999).

This is not to say that institutional issues have been ignored totally. Thus, Tripp (1989 and 1993) and Echeverria (1998) have argued that the core of the problem relates to the need to satisfactorily define a new role for the State in agricultural research and to make its mandate and priorities explicit. They suggest that this needs to be accompanied by re-designing the institutional structure to allow it to fulfil this role. Tripp (1993) argues that all too often there is a tendency to look for alternatives to the public sector research (usual NGOs or the private sector) rather than concentrating on the better integration of its new role into the wider agricultural landscape. Economists need to take some of the blame for this, particular through their tendency to "bisect" roles into public or private domains. This relates to the rather rigid way in which the concepts of rivalry (in the supply of knowledge) and excludability (the capture of propriety rights to knowledge) are used to predict which areas, through market failure, will need to remain in the public domain (Pray and Umali-Deininger, 1998). A more realistic view of future agricultural research systems recognises a diverse array of potential participants in research funding and execution and a large

number of points of intersection between funding sources and research executing organisations (Echeverria, 1998; Pray and Umali-Deininger, 1998). In this respect the concept of public/private sector partnerships is gaining increasing momentum.

In fact, private sector involvement is becoming increasingly important in a variety of respects. For example, the role of Growers' Associations can now often be seen as a key focussing device for R&D. In Colombia, for example, a recent UNCTAD (1999) review shows how in crops as different as cut flowers, coffee and sugar, such associations (called "gremios") now play a major role in R&D, extension, training, and the provision of linked services to farmers. And in so doing they allow the state to take on more strategic tasks for the agricultural sector as a whole. Contract farming schemes are another type of relevant development that is increasingly appearing on the scene. By this is meant the practice of a central node establishing purchase contracts with farmers. This usually involves the central node supplying technology, markets, and credits for inputs such as fertilizer. The farmer supplies land, labor, and tools in growing the crop, which is then sent to the central node for finishing, grading, packaging and sale—often to an export market. Although such schemes are not without their problems (see, for example, Porter and Phillips-Howard, 1997) they are an increasingly important mechanism for technological development in many parts of the Third World.[17] The central node is often a multinational company. An example here is the firm Arbor International that sources fresh food from countries like Zimbabwe and then supplies it to prestigious retailing firms in the UK. In this case the intermediary provides technology, other key information, cold storage and airtight facilities, and direct access to a high value market.[18]

These types of institutional development are also starting to emerge in the CG centers. For example the International Institute for Tropical Agriculture (IITA) has used partnerships with private commercial organization to manufacture and distribute a biopesticide for the control of locusts in sub-Saharan African. IITA had initially hoped that enough of the biopesticide could be manufactured by its traditional partners – the African NARS. However, the production process demanded specialist facilities and quality control procedure that were best achieved by identifying commercial enterprise partners and transferring the production know-how them (IITA, 2000).[19]

A feature of such institutional developments is that they integrate R&D into the more general production system. And in so doing they appear to be rather successful, particularly with respect to the poor farmer. A good example here is the findings of Tendler's research in Northeast Brazil. Tendler (1993) studied nine World Bank funded development projects targeted at poor farmers in a region afflicted with problems of semi-aridity and periodic drought. All of them exhibited remarkable degrees of success despite the presence of unpromising initial conditions. And the factors behind successful performance involved institutional change at many levels. Especially significant were the role of "demanding user agencies *outside* extension

and research; shorter time horizons and more focussed tasks; localised credit subsidies with automatic sunset provisions and penalties for non-performance; a strong presence of municipal elites, normally avoided in the design of such programmes; and an equally strong and complementary presence of more centralised public sector actors."[20] Tendler goes on to suggest that conventional support systems that are expensive, long term and supply driven may not always, or even generally, be the right way forward. "Agricultural, rural, and area development projects, in other words, present significant opportunities to build institutions in research and extension, but not in expected ways."[21]

An Alternative Conceptual Framework

It is therefore difficult to see how the conventional conceptualisation of innovation in agriculture as a linear process can help us here. In fact, we would argue that it has probably been the *cause* of the problem to a large extent. However, many elements of the institutional question raised by the new agendas for agricultural research are all too familiar to contemporary policy analysts of the innovation process in other sectors. A useful concept to bring to bear is the approach of viewing technical change in systemic terms, where flows of knowledge between actors and institutions in the process, and the factors that condition these flows, are critical to innovative performance. This helps capture the dynamic, process nature of innovation while at the same time recognizing that it is determined to a large degree by its institutional context.

Central to this view of the world has been the recognition that innovation increasingly takes place at the interface of formal research and economic activity, thus denying the primacy of either knowledge creation and validation institutions (R&D bodies such as universities, etc.), or knowledge application institutes (usually enterprises). Rather it is partnerships *between* these types of actors that are important. As economies increasingly become dependent on the production, distribution and use of knowledge—"knowledge based economies" (OECD, 1996b), analysts has focused on flows of knowledge. This analysis stresses the importance of these institutions as nodes in a system where their interaction and interactive relationship along with other contextual factors is key to these knowledge flows. Attempts to understand the structure and dynamics of such systems are at the core of modern thinking about the innovation process (Clark, 1995, 2000; Edquist, 1997; OECD, 1997).[22]

This approach has come to be known as the "national systems of innovation" (NSI) framework (Freeman, 1987; Lundvall 1992). A NSI is defined in number of slightly different way (Freeman, 1987; Lundvall, 1992; Nelson 1993; Patel and Pavitt 1994; Metcalfe, 1995). Broadly speaking it can be described as the system or network of private and public sector institutions whose interactions produce, diffuse and use economically useful knowledge. The component parts of the systems and their interactions are determined by culturally defined norms, historically determined institu-

tional developments, national priorities and are defined by geographic boarders and national policies. It is not necessarily suggested that national governments have explicitly developed innovation systems in this way, although some clearly have. However, in economies where such interactive systems have evolved successfully, innovative performance has been strong and this has been reflected in rapid rates of economic growth (Freeman, 1987, 1991).[23]

Rather than presenting a blueprint for institutional reform, NSI is concerned with mapping and evaluating channels for knowledge flows, identifying bottlenecks and suggesting appropriate remedial action. In this sense NSI presents a set of analytical principles for understanding the innovation process in a national context, and identifying leverage points for enhancing innovative performance. These principles include:

- Assessing the extent of institutional interactions;
- Assessing impediments to flows of knowledge between nodes;
- Assessing the opportunities for and constraints to interactive learning and institutional innovation; and
- Assessing policy and practices that can give rise to failures of the component parts working as a system.

We believe that the value of this approach to agricultural research systems is that it allows the sector to be viewed in a much more holistic fashion. Of most importance is its ability to encompass the range of institutional forms–private, NGO, farmer association etc –that actually make up the research system. This allows us to do two things. First, it places the public sector in a wider context and allows it to identify what its most appropriate role might be in the system and how this might evolve. Second, it identifies the types of institutional linkages that are starting to become important and the types of systemic failure that are constraining otherwise productive relationships. For instance, if partnerships in agricultural technology development are to emerge as a core methodology, the analytical principles of NSI will be invaluable in designing a policy framework to foster such collaborative arrangements. Similarly, the analysis can be used in the context of policy formation to identify leverage points where innovative performance can be improved and ways in which this can benefit the poor specifically.

Another way of looking at the same approach is to borrow the French economists' term *filière*–literally "thread."[24] The concept here is that a specific theme is used as organising principle for the economy (or parts of it). Institutions (public and private) are focused in their function to support this theme and the synergy that results can be enormous. Examples of this include countries like Costa Rica where the environment has been used as such an organising principle–hence the clusters of related economic activity around eco-tourism. It could be argued that the same approach is being adopted in Southern India with the information technology industry.

One advantage of the *filière* concept that complements the NSI approach is that it can used to focus sub-nationally and in specific sub-sectors. It also appears that the idea of clustering different institutions around specific objectives or themes has relevance to the different policy agendas emerging for agricultural research. For example, it might be the case that it is useful to think about ways of clustering institutions around agendas such as poverty, export development or environmental protection.[29] It is easy to envisage how national governments might want to concentrate on selected themes, while leaving different agencies to organise other themes. The NSI principles could then be used to concentrate on ways of improving knowledge flows within these clusters through adjustments in the policy framework.

The suggestion here is not that these approaches should replace existing approaches, but rather that they supplement them. Economic analysis of returns to investment in research will still be important. Participatory methods, in an appropriate institutional context, will be a key tool in increasing flows of knowledge between farmers and other parts of the innovation system. However, these approaches need to accommodate an analytical approach that deals with institutional issues more directly.

While such approaches, particularly the NSI, are now mainstream with organisations such as OECD and UNCTAD[30], their application in the agriculture sector of developing countries is mainly untested. Further work is required to develop its application in contexts where the institutional nodes in the system may be NGOs and other civil society organisations or instances where market incentives for technological change are absent. However, as the circumstances in the developing country agricultural sector suggest an overriding need for a more inclusive approach to understanding technology development as a process, NSI should provide a useful starting point.

Conclusions

Institutional arrangements of agricultural research are undoubtedly emerging as a key constraint in efforts to apply excellence in science to efforts to alleviate poverty. This perspective has received little attention over the last forty years. As a result, not only are there growing crises in many agricultural research systems, but also there is very little comfort to be found in current policy treatments of this problem. From a policy perspective, many of the shortcomings of existing conceptual approaches to technology development could be supplemented by the analytical principles that NSI provides. A key lesson for policy analysts is the need to be able to engage with the process nature of innovation and the disciplinary challenges that its qualitative nature may present. For those charged with reform of the system there is a need to be prepared to accommodate sufficient scope for the continuous process of institutional change that is implicit in much of the current thinking about the way innovation actually works.

Why there is reluctance to engage with institutional questions is not an easy question to answer. We suspect, however, that it has a lot do with the

interactions of three factors. The *first* is a reluctance to engage with complexity. It is much easier to operate with a simple agenda simply because all can understand and identify with it easily, for obvious reasons. Rather like putting a man on the moon, clarity of mission can help to mobilise resources and provide the stimulus for concerted action. The problem is, of course, that if the mission is actually the wrong one (or only partly so) then the waste of resources can be considerable. The *second* factor is the inertia of outdated institutions and procedures. In the case of LDCs agriculture the institutions put in place to apply the green revolution may have been appropriate at the time but it is clear that these times have long gone, while the institutions themselves still show a marked reluctance to adapt and change. The *third* factor is perceptions of threat on the part of relevant parts of the public sector, particularly the research sector itself. Although actually often misconceived, there is an impression that jobs are at stake and that hard-earned intellectual capital will be suddenly devalued. Of course, the reality is that such devastating outcomes are much more likely under the continuation of the *status quo* but history tells us that often vested interests are reluctant to come to terms with the necessity for radical change.

For this reason we feel that the drive for institutional reform be treated with great care, particularly where sensitivities are strong. But having said this it is also quite clear to us that the agricultural research agenda in the Third World has changed irreversibly. The issues are more varied, more inclusive, more complex and ultimately more directly concerned with how to deal with significant poverty in many countries. It is now the responsibility of policy makers to grasp the nettle of institutional reform and make sure that the problems of the twentieth century do not re-appear in different guises in the twenty-first.

Notes

1. See Carney (1998). Actually the debate about economic growth and its distributional consequences is a very old one. Writing in the 1970s Keynes (1971-73) was convinced that in 100 years time the economic problem would be solved, at least in the then industrialized countries. More recently, Hirsch (1977) introduced the concept of "positional goods" to explain the apparent contradiction that high rates of growth appear to be leading to more unequal income distribution both nationally and internationally.
2. The CGIAR (established in 1971), is an informal association of public and private sector members that supports a network of sixteen international agricultural research centers. It is managed and core funded by the World Bank.
3. For detailed discussion see Anderson (1991), Anderson et al. (1991), Jennings (1988), Reece (1998).
4. Anderson (1991) quotes the term *notable* from contemporary Rockefeller Foundation archive material.
5. For a more detailed discussion of this notion, see Clark (1995, 2000).
6. For more detailed accounts of the spread of high yielding varieties and consequent impacts on production see for example Byerlee and Moya, 1993 and Dalrymple, 1986a,b.
7. Lipton and Longhurst (1989) remains one of the best informed attempts to explain these issues and provides a comprehensive review of evidence and earlier debate. See also Horton and Eliot (1993) who argue that the lack of poverty impact is especially telling in Sub-Saharan Africa.

8. Environmental concerns started to emerge in the developed world in the 1960s with such seminal works as Rachel Carson's *Silent Spring* published in 1963. By the early 1970s there was a growing "green" movement in both Western Europe and North America.
9. See for example, Pearce et al. (1989) and Common (1995).
10. See for example, Siva (1988), CSE (various years).
11. A good example of this is the collaborative IPM research implemented through Southern India by the NGO Agriculture Man and Environment.
12. A subset of this approach concerns the conceptualisation of agricultural production as a system and the need for this to be appreciated in the R&D process. See for example, Collinson, 1987. The associated farming systems research debate has been mainly methods driven and has struggled to find explicit forms in an appropriate institutional framework. For example, the integration of different disciplines has been particularly difficult to achieve organisationally, as has the ability of existing institutional structures to genuinely accommodate farmers in the research process (Biggs, 1989; Ewell, 1989; Farrington and Martin 1991, Biggs and Farrington, 1993, Biggs, 1995).
13. For example, Okali et al., (1994) (see also Sumberg and Okali 1997) criticised the way in which the advocacy associated with these populist approaches has tended to polarise the debate concerning formal and farmers' research, without recognising the potential synergy between the two.
14. Abundant examples of this methods-driven debate can be found in FLA notes. For criticism see Tripp 1989, Biggs 1995; Biggs and Smith 1998; Hall and Nahdy 1999.
15. For example, Muthyunjaya and Ranjitha (1998) articulate the multitude of agendas the Indian systems are trying to cope with.
16. For a recent overview, see Byerlee (1998).
17. See also Hall et al. (1998) for recent India examples.
18. See UNCTAD (2000), Chapter 1.
19. An earlier example can be found in the EPMR of ILRAD (now ILRI) in 1991 where the reviewers recommended the establishment of strategic private sector alliances. Needless to say this recommendation was ignored. See ILRAD (1991).
20. Tendler (1993), p. 1567. Italics are ours.
21. Ibid. p. 1576.
22. Carlsson (1995) discusses a similar concept using the term technological systems. See also Clark (2000) for a treatment that stresses formal information theory.
23. Edquist (1997) provides substantial discussion on the precise definition of national innovation systems, and the way different authors have interpreted the concept and its shortcomings.
24. See Clark (1991) for a more detailed discussion.
25. The DFID "Sustainable Livelihoods" thematic is close to this view. See Carney (1998).
26. See also UNCTAD (1996).

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