New Asian Challenges: Missing Linkages in Asian Agricultural Innovation and the Role of Public Research Organisations in Four Small- and Medium-Sized Asian Countries

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Asian agriculture is faced with major new challenges as a result of globalisation, urbanisation and environmental problems such as climate change. To meet these challenges, Asian agriculture needs to become more knowledge intensive and innovation oriented. This article frames the new Asian challenge in terms of innovation theory, emphasising the importance of the co-evolution of technological and institutional change and linkages between actors in open, interactive innovation processes. It studies the performance of agricultural research and technology organisations (RTOs) in four small and medium-sized South and Southeast Asian economies: Sri Lanka, Pakistan, Indonesia and Vietnam. A key performance issue is the linkages between actors, which is a key weakness in the agricultural innovation systems of most Asian countries. The need for effective linkages is growing as agricultural production and innovation are becoming increasingly complex due to the impact of the consecutive green, sustainability, biotechnology and supermarket revolutions. Linkages are in short supply, but the demand for them is exploding. As a consequence, traditional public agricultural research organisations in Asia, created at the time of the green revolution, no longer play a central role in agricultural innovation as they did when countries faced only one challenge.

Keywords: Innovation, innovation systems, linkages, agriculture, public research organizations, Asia

Introduction: Challenges to Asian Agriculture

SINCE THE MID-1970s, the agricultural sector in Asia has witnessed rapid growth in agricultural production and productivity. In the 1975–2005 period, the production of grain doubled, that of fruit and vegetables quadrupled and meat production increased six-fold (FAOSTAT, 2009). Production has grown more rapidly than population growth and has, in many countries, been accompanied by poverty reduction

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in rural areas. Despite these successes, important new challenges are emerging. First, demand is growing even more rapidly than production, leading to increasing imports of food and raw materials. According to FAOSTAT (2010) data, agricultural production in Asia between 1990 and 2007 increased by 79 per cent from 472 to 845 billion international dollars. In the same period, imports grew by 180 per cent from 85 to 238 billion international dollars. These changes have occurred mainly as a result of rising incomes across Asia and changing consumption patterns, which are showing a shift towards a more Western diet. In the future, significant increases in food production in Asia will be needed to keep up with the demands of a growing, more affluent population.

Second, whereas demand is increasing, the resource base from which to feed a larger and wealthier population is declining. Prime agricultural production land is disappearing rapidly due to a combination of erosion, urbanisation, industrialisation and the use of land for recreational activities. Third, since the beginning of the twenty-first century, the production of biofuels (from maize, soybean and sugar) has grown rapidly, stimulated by fiscal measures in Europe and the United States. The resulting increasing competition between food and energy crops led to rapidly increasing food prices in the 2005–2008 period. Fourth, although considerable progress has been made in many Asian countries, rural poverty, especially in marginal production areas, remains high and continues to be an important challenge for policy makers.

To meet these four challenges, Asian agriculture will need to produce more and better quality products with fewer natural resources (land, water and chemical inputs). The FAO (Food and Agriculture Organization of the United Nations) High Level Expert Forum on 'How to Feed the World in 2050' (FAO, 2009) estimated that agricultural production between 2009 and 2050 will have to double in size. This is a major challenge because the 'easy' productivity gains resulting from the more intensive use of agricultural inputs are a thing of the past as environmental limits to growth have been reached in many farming systems (World Bank, 2008). Another doubling of production while protecting the environment can only be achieved if agriculture becomes more productive and sustainable at the same time, which, in turn, is possible only if production becomes more innovative and knowledge intensive. A more innovative agriculture combines novel technologies and management practices in clever new ways.

Agricultural research and technology organisations (RTOs) have always played a key role in generating, adapting and disseminating new technologies and management practices—certainly in developing countries. Asian agricultural RTOs, for example, have made important contributions to technological innovation in food crops, including rice, where Thailand has become an important innovator, and plantation crops, such as rubber, where Malaysia has become a leading innovator. However, despite these successes, the question remains whether Asian agricultural RTOs can cope with the combination of these four challenges. This article therefore explores the different roles played by these organisations in the innovation process, and offers a two-fold explanation of why many Asian RTOs are not effective actors

in national agricultural innovation systems. On one hand, it is argued that to promote innovation, rather than engage in research, RTOs must be effectively linked to other actors (such as farmers, input providers and processors) in the innovation system. Asian agricultural RTOs seem to have a limited capacity to establish such linkages. On the other hand, over the last 50 years, agricultural production and innovation systems have become much more complex as they have moved from a linear green revolution model to more complex (networked) techno-institutional paradigms in which natural resource management, biotechnology and global agri-food chains play increasingly important roles. Although the need to engage in a variety of innovation linkages is becoming more important, the capacity of RTOs in Asia to establish and maintain such linkages has lagged considerably as the possibilities for institutional innovation are much more limited than the capacity for technical innovation. This is caused by weak management, a top-heavy bureaucracy, centralised decision making and a lack of incentives for innovation, a situation that has changed little in the last decade (Byerlee and Alex, 1998, Beintema and Stads, 2008).

The article lays out this argument by first posing a starter question: what do we actually know about innovation in general (section 2) and the role of agricultural RTOs in innovation in particular (section 3)? Public and private R&D investment is considered to be a factor, as well as what determines the performance of public RTOs. The latter requires an in-depth look at the linkages of agricultural RTOs (section 4). Next, the changing context of agricultural innovation in Asia is covered by introducing four different innovation paradigms (section 5) that have had an impact on the growing complexity of linkages, which have to be managed by RTOs to become or remain effective (section 6). The article concludes with an assessment of whether Asian RTOs are geared towards the new challenges (section 7).

Theoretical Perspectives on (Agricultural) Innovation

This section discusses the role of technology and institutions in innovation and the ways in which innovation processes are organised in innovation systems and networks.

The Co-Evolution of Technologies and Institutions

Following the seminal work of Schumpeter (1976), innovation has been studied by a wide variety of scholars in a number of academic disciplines including economics (Baumol, 2002; Nelson, 1987; Dosi et al., 1988), management theory (Drucker, 1998), sociology (Rogers, 1995) and geography (Hägerstand, 1967). The narrow interpretation of innovation, referring to technical innovation, has moved towards a wider, heterodox interpretation, which includes not only technical but also organisational and institutional innovation.

Schumpeter was the first mainstream economist to identify the key role played by entrepreneurs in the innovation process. He distinguished innovation from

invention and used the former term in a very broad sense, defining the task of the entrepreneur as 'to reform or revolutionise the pattern of production by exploiting an invention or, more generally, an untried technological possibility for producing a new source of supply of materials or a new outlet for products, by reorganising an industry and so on' (Schumpeter, 1976: 132). Innovations are any 'new combinations' of existing or new technologies or practices, and include new products, processes, distribution methods, ways of operating in markets and management practices and organisational structures. An accompanying insight in the Schumpeterian tradition is that technical innovation needs to go hand in hand with institutional and organisational innovation (Radosevic, 1998).

Institutional and Organisational Change

Institutions involve laws, rules, regulations and incentives—and the organisations that are responsible for their implementation and/or maintenance. New laws and regulations are profoundly affecting innovation in the agricultural sector worldwide. Important institutions include trade and investment regulations, intellectual and other property rights and food quality and safety standards. Increasingly, these rules and standards originate with international organisations such as the World Trade Organisation (WTO) or the International Organisation for Standardisation (ISO). In the private sector, supermarkets and international food companies have emerged as major players in the agricultural innovation arena by organising global agri-food value chains that are held together by a range of public and private standards for production and processing.

Although international institutions are major drivers of change in this globalising world, national institutions (e.g., land tenure, labour laws and markets) and organisations (agricultural ministries and research and extension organisations) in developing countries are often seen as obstacles to innovation. Unclear property rights and top-heavy bureaucratic structures and procedures limit the potential for change. Public agricultural research organisations, for example, find it difficult to address the increasingly complex R&D and innovation agenda resulting from internationalisation and pressure from stakeholders to improve performance. To address these problems, new policies, structures and incentives are needed, above all to promote interaction among a broad range of agricultural innovation actors. However, institutional change is difficult to achieve, mainly as a result of what North, (1995) calls 'institutional path dependence', which explains why outmoded organisational structures, rules and incentives tend to persist.

Nelson (2008: 1) stresses the role of institutions in economic growth, but adds, 'with few exceptions the exploration of the role of institutions has not been connected with a coherent analysis of the relationships between institutions and institutional change and technological advance'. He argues that technical and institutional change (or physical and social technologies, as he calls them) need to go hand in hand, and that physical and social technologies co-evolve. Institutions are important in the innovation process as 'institutional change, and its influence on

economic activity, is much more difficult to direct and control than technological change, and hence prevailing institutions often are drags on economic productivity and progressiveness' (Nelson, 2008: 2).

Many authors (e.g., Kash and Rycroft, 2000; Radosevic, 1998; Nelson, 2008) see the integration or co-evolution of technical and institutional innovation as a key issue in innovation processes. New technologies often require new rules (institutions) and organisational arrangements. 'The self-organising networks capable of innovating complex technologies are distinguished by the fact that they co-evolve with their technologies. Co-evolving networks and technologies are appropriately seen as socio-technical systems, in which the networks and the technologies continuously shape each other' (Kash and Rycroft, 2000: 820). Perez (2010) refers to 'techno-economic regimes' as models or paradigms in discussing the co-evolution of technologies, institutions and organisations.

Innovation Systems, Networks and Actors

Technologies, institutions and the actors that link them are often described in terms of innovation systems or networks. An extensive literature on national innovation systems (e.g., Nelson, 1993; Edquist and Johnson, 1997) has emerged as a body of formally codified knowledge, which has been widely accepted in academic and policy circles. Although there are differences of opinion and controversy in the national innovation system community on some issues, there appears to be broad consensus on the importance of innovation as an interactive process and on the rejection of the way innovation is treated in neoclassical economics (Sharif, 2006).

While the national innovation system literature stresses the importance of national policies and institutions in shaping innovation, the meso-level sectoral innovation system literature (Malerba, 2005; Asheim and Gertler, 2005) emphasises the importance of sectoral characteristics that affect innovation, such as agricultural cropping patterns and land tenure systems, and recognises that innovation is not necessarily constrained by national boundaries. At the micro level, the literature on innovation networks (Powell and Grodal, 2005) emphasises the roles and positions of actors, the types of linkages and the extent of actor embeddedness in networks (Uzzi, 1997; Powell and Grodal, 2005). The analysis of the performance of agricultural RTOs in this article draws on the innovation system literature, especially at the national level, and on the network and linkage literature.

Agricultural RTOs are key actors in innovation systems or networks as they play a number of important roles. First and foremost, they produce new knowledge and technology and disseminate it among users (agricultural producers). Traditionally, in the linear view of innovation, such organisations have been seen as core institutions that generate and transfer new technology to a variety of users, who are passive recipients. Newer approaches to innovation and the production of knowledge (Gibbons et al., 1994) emphasise that innovation is a multi-faceted, interactive

process (van Tulder et al., 2000), which points to new roles for agricultural RTOs, such as system integration—bringing together a range of actors. However, traditional agricultural RTOs in Asia are not well placed to take up these roles in changing innovation systems.

Recent developments in innovation have been characterised by Chesbrough (2003) as constituting a shift towards 'open innovation'. Open innovation systems are based on the notion that multiple sources of innovation exist, that innovation often originates in unexpected places and that there are often benefits in sharing, rather than protecting, ideas and technologies.[1] Companies, lead users, universities, research departments, public research organisations, consumers and NGOs can all play legitimate roles in the innovation process. In fact, in the agricultural sector, which is characterised by many technology users in different locations and (at least traditionally) knowledge largely in the public domain, innovation has always been an open process. Given that multiple actors are required for the generation, dissemination and adoption of innovations, linkages among networks of actors are a key condition for innovation (Hall et al., 2001).

Agricultural Research and Technology Organisations in Asia

Given the abovementioned developments in the thinking on innovation, the following two-fold question becomes relevant: what has the level of performance of agricultural RTOs in the four Asian countries under consideration traditionally been, and has performance been influenced by the ability of the organisations to engage in innovation linkages? This section presents an overview of the dynamics of agricultural RTOs in Asia by analysing public and private R&D and innovation activities in terms of investment (quantitatively), and the resulting activities and outputs (qualitatively).

Public Agricultural Research and Innovation Actors in Asia

Public agricultural research in Asia started with the establishment of botanical gardens in the early nineteenth century in Java (Bogor) and Ceylon (Peradeniya). Until the 1960s, both public and private agricultural research focused on plantation and export crops. In the 1970s and early 1980s, public agricultural research organisations (focusing on food crop research) expanded rapidly. This was a time of government-led development, and private agricultural research in a number of countries was brought under government control, such as plantation crop research in Sri Lanka and Indonesia (Tabor, 1995).

By the early 1980s, in response to rapidly rising oil prices in the 1970s and sharp falls in agricultural commodity prices, on which many developing countries depended for export earnings, a period of structural adjustment started, with an emphasis on sound government budgets, realistic exchange rates and greater attention to the role of the private sector (Tabor, 1995). Growth in public sector

expenditure was reversed in many developing countries, and, faced with a political inability to reduce the number of staff, the only option for public research organisations was to reduce operational expenditure to such a level that virtually no meaningful research work could be undertaken. In many Asian countries, including Indonesia, Pakistan and Sri Lanka, among others, international donors stepped in to fill the gap and provided soft loans and grants to support agricultural research and extension.

In many countries, including those just listed, donor funding was also used for institutional capacity building, especially to coordinate the work of a host of institutions under a single national 'apex body'.[2] While these governance bodies differ considerably in the roles that they play in the agricultural research and innovation system, they have had two main effects: improved coordination of the activities of those components of the innovation system that are under their control and, in general, the centralisation of decision making.

By the late 1980s it had become clear that centralised research bureaucracies could not address many of the new demands on agricultural research organisations imposed by a more knowledge-intensive agriculture, the growing role of the private sector, new regulatory frameworks in relation to internationalisation and a broader research agenda (including the need to address environmental concerns and make agricultural research relevant to poverty alleviation). In response, donors and national governments started to implement a number of measures to improve the levels of performance and accountability of public agricultural research systems. These included the separation of research funding from research implementation, introduction of competition between research providers, involvement of technology users in planning and priority setting, promotion of partnerships between public and private actors and decentralisation of research.

Private Agricultural Research and Innovation Activities

Innovation in agriculture was originally an activity undertaken by individual farmers and communities to develop improved crops, livestock breeds and farm management practices. In the nineteenth century, more formal institutional arrangements emerged in the form of agricultural universities, publicly funded experimental stations and private companies that sought to commercialise new seeds and planting material, machinery and agro-chemicals.

In developed countries, private agricultural R&D is generally greater than public agricultural research investment, whereas in developing countries (including those in the Asia-Pacific region), the situation is the opposite. Pardey, Alston and Piggot (2006) show that private sector agricultural research expenditure in developed countries accounts for 55 per cent of the total expenditure, whereas in Asia over 90 per cent of agricultural research is publicly funded.

However, private agricultural research investment data seriously underestimate the importance of the private sector in agricultural innovation. In fact, it can be argued that most of the private sector inputs into agricultural innovation

are not counted as R&D results. These include the timely provision of production inputs, marketing, adding value through food processing, organising food chains and the upgrading of production through standards—all of which are important contributions to agricultural innovation.

Assessing the Performance of Agricultural RTOs

Field work was undertaken in four countries (Indonesia, Pakistan, Sri Lanka and Vietnam) as part of a project, which was funded by the Asian Development Bank (ADB) from 2000 to 2004, to introduce performance-based management practices into public agricultural research organisations. Countries and organisations were selected by the project team from the International Service for National Agricultural Research (ISNAR) and the ADB to represent South and Southeast Asia, and to include research organisations that had expressed a willingness to improve their organisational practices.

An in-depth assessment was conducted of the performance of six agricultural RTOs in the four countries in Asia under consideration. We used the framework for measuring R&D effectiveness that was developed by Szakonyi (1994a, 1994b) and elaborated for agricultural research organisations as the Organisational Performance Assessment System (OPAS) (Peterson et al., 2003a; Gijsbers, 2009). The method uses self-assessment, supported by external facilitation. The OPAS focuses first, on the assessment of the number and types of outputs produced by a research organisation, and second, on the analysis of the management processes that drive the production of these outputs.

A key conclusion from this output analysis is that, with regard to the types of outputs produced, agricultural RTOs in Asia perform a broad range of functions in the innovation system. Not only do they produce research outputs, such as new technologies and production practices, they are also all quite active in the production of non-research outputs, including training, technology transfer, the dissemination of information and the provision of a range of public services such as disease monitoring, quarantine services, soil analysis, artificial insemination, animal feed analysis and seed production.

The OPAS assessment of management practices reviewed a broad set of practices that drive performance. These include, amongst others, the capacity to plan strategies to respond to changes in the external environment, select research priorities, manage human resources and assess staff performance, evaluate research results and manage linkages and partnerships with a range of different actors (government, private sector companies, farmers, etc.). Each of those practices was assessed based on the extent to which it was used at the institute, using a four point scale, where 0 = not used, 1 = occasionally used, 2 = routinely used, and 3 = continuous improvement.

A key finding from the management analysis is that the most important weaknesses identified in all four countries are the result of ineffective linkages of different types—five of the seven most important weaknesses at the six research institutes concern linkage issues (Table 1).

Table 1
Key Management Weaknesses Identified by Agricultural Research Managers

Linkages with the international private sector
Staff performance assessment
Linkages with international donors
Governance of the research system
Linkages with policy makers
Linkages with the national private sector
Involvement of external stakeholders

Source: Gijsbers (2009).

Agricultural RTO managers consider linkages with the national and the international private sector (or rather the absence thereof) as the most problematic. Those with policy makers and international donors are also seen as key issues. Most organisations also consider farmer participation in research planning and implementation to be a serious problem. Other weaknesses concern the governance of the research system and the inability to effectively assess staff performance and manage human resources (Gijsbers, 2009).

RTO Linkages in Asian Agricultural Innovation Systems

What does the problematic nature of agricultural RTO linkages in agricultural innovation systems imply in practice? Linkages can be defined as coordinated channels for the exchange or flow of technology, information and resources between organisations in an agricultural innovation system (Peterson et al., 2003b). Such exchange can be achieved in different ways by establishing linkage mechanisms that address specific purposes or functions. Linkage mechanisms are procedures that enhance technology generation and exchange and enable the flow of information and resources. Examples include joint planning meetings carried out by key partners, memoranda of understanding, contracts between organisations, joint research programming and priority setting with partner participation and staff exchanges between organisations, among others.

In each of the four countries, an assessment was made of the effectiveness of linkages and partnerships between public agricultural research organisation and other relevant actors in the agricultural innovation system (Gijsbers, 2009). The linkage assessment and planning work followed a matrix-type instrument through which the linkages among innovation actors were systematically reviewed. The linkage assessments were carried out in a series of workshops at each institute by a representative group of staff and managers with representatives from other innovation actors, and involved external facilitators for process guidance. The workshops involved separate one-day working sessions with representatives from the most important potential linkage partners for agricultural research organisations: farmer groups, extension agencies (to cover downstream linkages related to technology transfer), policy makers, agri-food processing companies, input suppliers and NGOs.

In Indonesia, public sector decision making has traditionally been very hierarchical (Rohdewohld, 2004). Since the beginning of the *Reformasi* era (following the end of the Suharto regime), decentralisation has been a key issue in Indonesian society (Ahmad and Mansoor, 2002). However, collaboration and partnerships between the Indonesian Agency for Agricultural Research and Development (IAARD), the research arm of the Ministry of Agriculture, and other actors in the agricultural innovation system are new arrangements and few in number, and the involvement of stakeholders in IAARD decision making is virtually non-existent. Although IAARD had limited experience in setting up and managing new partnership and networking arrangements, it has made progress in developing different types of contracts to manage partnerships with a variety of clients—mainly because of the government's commercialisation policy, which was implemented after 2000. Nevertheless, commercialisation contracts are in place in only a few research institutes. In addition, it is important that not only formal but also informal networks for innovation be developed—with which IAARD has even less experience (Gijsbers, 2009). Poor linkages between agricultural research and extension organisations have resulted in a lack of attention in the research agenda to the problems of farmers and hampered the dissemination of research results (World Bank, 2007). Linkages between IAARD research organisations and farmer organisations with NGOs and universities have not been very effective (Fuglie and Piggott, 2006). However, IAARD has established effective linkages with international research organisations and policy makers.

In Pakistan, government policies towards the agricultural sector have been unfavourable (Ahmad and Nagy, 2002). The level of investment in public agricultural research has been very low, and linkages among agricultural innovation actors in Pakistan are constrained by the governance of the public administration system and the lack of operational budgets. Although the research system under the Pakistan Agricultural Research Council (PARC) is supposedly autonomous, in practice it is an integral part of the public administration system. It is characterised not only by the extreme centralisation of decision making but also by a severe lack of flexibility in operating arrangements (Afzal et al., 2003). The use of contracts with third parties is very limited, and there are no arrangements for research to become more market oriented (e.g., to retain and reinvest any revenues from services provided to producers). Research, extension and education services are highly compartmentalised, and cooperation between the public and private sectors is almost non-existent. Another constraint is that 'more than 90 per cent of the budget is allocated to salaries, leaving less than 10 per cent for administrative expenses and operational costs' (Greer and Husaini Jagirdar, 2006: 5). Establishing and maintaining effective linkages between actors in the innovation system should be a key public responsibility. It is also relatively costly in terms of operational expenses for travel, workshops or publications.

Sri Lanka's agricultural R&D system is small compared to that of the other three countries. Moreover, it is scattered over a large number of government ministries and

agencies (Stads et al., 2005). The Sri Lanka Council for Agricultural Research Policy (CARP), which was established to provide governance for and coordination of this fragmented research system, is neither mandated to play an effective governance role nor adequately equipped and staffed for effective coordination (Gijsbers and Springer-Heinze, 1997). The main research units in Sri Lanka are part of at least five different ministries and generally have neither the flexibility nor the instruments to engage effectively with other actors in the agricultural innovation system. There are, however, differences between ministries: the formerly private plantation crop institutes have more flexibility and better funding to support partnerships than have the food crop research institutes under the Department of Agriculture.

There are considerable differences between Vietnam and the other countries in the study with regard to the organisation of agricultural research linkages. Since the 1990s, a number of policy initiatives have been taken to strengthen the linkages between research and the productive sector. These include first, the freedom for research organisations to enter into research contracts with the productive sector. Second, according to Bezanson (2000: 19), research organisations have been given 'much increased flexibility to develop and provide, in addition to research, a full range of services, including technology transfer, consulting services, experimental and pilot manufacturing, etc.'. Crucially, unlike the case in most other countries, research institutes in Vietnam are allowed to retain the profits that accrue from research or technology transfer activities. This may have led to the crowding out of genuine research, but it has also resulted in the creation of linkages with the productive sector for the provision of a number of knowledge-based services.

A major change that has occurred in Vietnam since 2000 is a very significant increase in government expenditure on public R&D, although the average expenditure per researcher and research intensity levels remain lower than those in many other Southeast Asian countries (Stads and Hai, 2006). Another change is the steep growth in foreign direct investment (FDI), which has had a number of impacts on agricultural innovation, most importantly the growth of agricultural support industries, which can and should replace the role that research institutes played in the supply of agricultural inputs when the market economy was much less developed. FDI growth is also transforming supply chains and the retail sector and inducing innovations in primary production.

An Assessment of Linkages in Asian Agricultural Innovation Systems

Linkages are defined as coordinated channels for the exchange or flow of technology, information and resources between organisations in an agricultural innovation system (Peterson et al., 2003b). Effective linkages and partnerships between organisations are essential to transfer research results to farmers and input suppliers. Linkages are also needed to pass on to policy makers and researchers relevant information on production constraints at the farm level and in general to facilitate inter-organisational experimentation, learning and by implication, innovation (Nooteboom, 1999; Douthwaite, 2006). The importance of linkages has

been recognised in not only the agricultural innovation literature (Merrill-Sands and Kaimowitz, 1990; Temel, 2004) but also the innovation literature in general. The triple-helix model of innovation (Leydesdorff, 2005) emphasises the key importance of interaction among knowledge institutes, including those in academia, industry and government. Innovation linkages are especially important for small and medium-sized enterprises (Rothwell and Dodgson, 2007).

Table 2 presents the assessment of the most important strengths and weaknesses of the linkages between the most important partners of the public agricultural research system. A number of findings emerge from this assessment. First, partnerships in agricultural research, development and innovation are overall quite limited in number and in scope of collaboration.[3] Second, there are remarkable differences between the countries with regard to the overall effectiveness of the linkages maintained by public agricultural research actors. Pakistan has the most difficulty in maintaining adequate linkages, with Indonesia and Vietnam considerably more effective in doing so.

Table 2
Assessment of Linkages between Public Agricultural Research Organisations and Other Innovation Actors

Country Function	*Indonesia*	*Pakistan*	*Sri Lanka*	*Vietnam*
Extension	–	– –	–	–
Farmers	–	– –	+/–	+/–
Private sector	–	– –	+/–	+/–
Research organisations	+	–	–	+
International donors	+	+/–	–	++
Policy makers	+	–	–	+
NGOs	–	–	–	–
Score	13	5	9	16

++ Very strong (4 pts), + Strong (3 pts), +/– Moderate (2 pts), – Weak (1 pt), – – Very weak (no pts)

Source: Gijsbers (2009).

Third, partnerships in agricultural innovation function mainly where they are promoted through donor funding. Research organisations in Indonesia and Vietnam benefited considerably more from donor funding than either Pakistan or Sri Lanka. Multilateral donors such as the World Bank and Asian Development Bank are important actors and play a key role in insisting that public sector research organisations engage with other organisations.

Fourth, donor pressure, changing government policies, more open markets and decentralisation contribute to public research actors becoming more receptive to the need to work in partnerships. However, a change in attitude is required of researchers and managers in public research organisations, who have functioned in a highly centralised and hierarchical system for most of their careers. More importantly, changes are required in decision-making processes, to allow horizontal interactions to happen.

Fifth, linkages and partnerships that depend on donor funding are not sustainable. At the same time, national research organisations that do not have adequate operational budgets for their research staff can hardly be expected to make funding available for networking with other organisations.

In summary, the actual capacity of Asian agricultural RTOs to engage in innovation linkages is found to be rather limited, despite the great need to establish such linkages with a variety of different actors due to the increasing complexity of agricultural production and innovation systems.

The Growing Complexity of Agricultural Innovation in Asia

Agricultural innovation in Asia has gone through dramatic changes since the 1970s. No fewer than four major revolutions have transformed the way that new knowledge is produced and disseminated and the roles of the actors involved in the innovation process. This has major implications for agricultural RTOs, which, in general, have not been able to change along with the changing context and are therefore in danger of losing relevance. Parayil (2003) describes agricultural innovation in Asia in terms of two different technological trajectories: the green revolution and the gene revolution. This article expands Parayil's analysis by presenting four different and consecutive 'revolutions', which are linked to four different 'techno-institutional paradigms' that have shaped and continue to shape agricultural innovation processes in Asia, and which provide the context in which agricultural RTOs are functioning: the green, sustainability, biotechnology and supermarket revolutions.

The green revolution has been extensively described in the literature (Griffin, 1979; Evenson and Gollin, 2003; Smale, 2005). Based on new high-yielding varieties (HYVs) of rice, wheat and maize and in combination with agro-chemical inputs and the expansion of areas under irrigation, the green revolution achieved spectacular successes, especially in the lowlands of Asia. The green revolution, sponsored initially by the Ford and Rockefeller foundations, was based on research breakthroughs in Mexico (wheat) and the Philippines (rice). Originally developed at the International Rice Research Institute (IRRI), the new varieties started to be widely disseminated throughout Asia from the late 1960s. Subsequently, national agricultural research institutes across Asia have played a key role in adapting and disseminating new, high-yielding rice varieties. The green revolution was essentially driven by international and national public research and extension institutes and supported by international development organisations such as the FAO and World Bank.

The post-green revolution model is based on three different but complementary criticisms of the green revolution: unsustainable cultivation practices, a reductionist approach to agricultural development and a top-down approach to technology development and dissemination. The main contributions to the post-green revolution paradigm come from three different but related bodies of knowledge: the

sustainability approach (exemplified in the integrated natural resource management models), the farming system approach and the participatory development approach. The post-green revolution model represents a sustainability revolution, which has in many respects been a 'quiet revolution' in comparison to the green one, and which has evolved from a counter-revolutionary movement into a mainstream one.

The gene revolution and the biotechnology paradigm started with the discovery in the 1950s of the structure of DNA and the scientific breakthroughs of genetic transformation in the 1970s. However, it was not until 1995 that genetically modified (GM) crops became available for commercial release (Qaim, 2005). Since then, the area under GM crops has grown very rapidly, especially in recent years (James, 2008). The key actors in the biotechnology revolution are the international life sciences, agro-chemical and seed companies.

The supermarket revolution is a very recent phenomenon, and according to Timmer (2005: 4), 'is transforming food retail markets, and the supply chains that provision them, at a faster pace than anyone imagined at the turn of the millennium, not only in medium income countries, but also in the poorer developing nations'. Supermarkets are becoming key actors in agricultural innovation by transforming the value chains that provision them. This phenomenon is especially prominent in the horticultural sector, not only in Asia but throughout the developing world (Dolan and Humphrey, 2000; Maruyama and Le Viet Trung, 2007; Reardon et al., 2003).

In the discussion of how supermarkets, in the context of (national and global) agricultural value chains, contribute to innovation, the concept of upgrading is central (Gereffi, 2001; Gereffi et al., 2001). Upgrading can take place within a value chain through better practices or improved logistics, or may involve the introduction of new value chains. It involves the improvement of production and logistics (e.g., transport and storage) processes to meet specific and explicit standards. Standards are needed to eliminate risk, which is important in complex chains where quality characteristics may not be immediately evident in the product itself. Standards include government-established safety standards, but industry-defined quality standards are rapidly becoming more important, so much so that Busch and Bain (2004: 321) argue that '…today it is the private sector, and retailers in particular, together with private standards that are at the centre of the transformation of the global agri-food system.'

The four techno-institutional paradigms can be seen as the result of combining two types of actors and two types of innovation. Core innovation actors may be public or private, and the innovation paradigm may be predominantly technology based or built on institutional innovation. The four paradigms represent fundamentally different views about the nature of agricultural development and agricultural innovation—as witnessed by the fact that they grew out of four revolutions. Table 3 presents a summary of the revolutions and the related paradigms and modes of governance.

That four techno-institutional paradigms of increasing complexity have developed over the years and co-exist in Asian agriculture indicates that agricultural

Table 3
Summary of Revolutions, Paradigms, Innovations and Actor Types

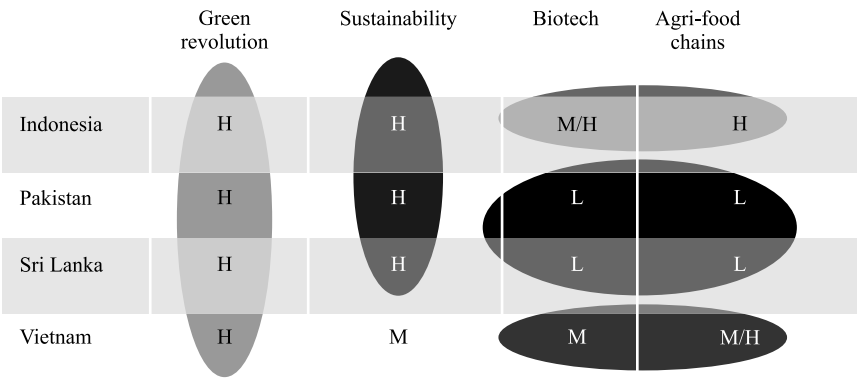
Revolution	*Take-off*	*Techno-institutional paradigm*	*Dominant innovation type*	*Dominant actor type*
Green Revolution	1970	Food Security Paradigm	Technological (seed-fertiliser packages), supply driven	Public (agricultural research organisations)
Sustainability Revolution	1985	Natural Resources Management Paradigm	Institutional (management practices), demand led	Public (research organisations, universities)
Gene Revolution	1990	Biotechnology Paradigm	Technological (genetic modification), supply driven	Private (life-science, seed, agro-chemical companies)
Supermarket Revolution	2000	Agri-food Chain Paradigm	Institutional, predominantly institutional, demand led	Private (supermarkets, logistics companies)

Source: Gijsbers (2009).

production and knowledge and innovation systems have become much more complex. Significant increases in the scale and scope of production, trade and innovation have been the main megatrends over the last 50 years, but with major differences among the four countries.

Figure 1 presents in a summarised fashion the prevalence of the different innovation paradigms in each of the four countries. The green revolution as the oldest innovation paradigm is well represented in all of them. Sustainability concerns are also widely integrated into the agricultural research and innovation agenda. The key differences are found in relation to the newer biotechnology and agri-food chain paradigms. A major difference can be seen between Indonesia and Vietnam on one hand and Pakistan and Sri Lanka on the other hand. The two Southeast Asian countries have seen heavy investment in biotechnology R&D and modern commercial horticulture. In the two South Asian countries, both public and private investment in biotechnology and commercial agriculture based on integrated agri-food chains has remained much more limited.

Figure 1
Importance of Innovation Paradigms in Four Countries



H = High, M = Medium, L = Low.
Source: Gijsbers (2009).

A common element of these more complex innovation systems is that, increasingly, issues cannot be solved, or even effectively addressed, by individual actors, but require action by a number of parties. Whether such (inter)action can and does in fact take place depends to a large extent on the linkages between actors in the agricultural innovation system.

Networks and the Growing Complexity of Organisational Linkages in New Innovation Paradigms

Why are linkages so problematic for public agricultural RTOs? An explanation should start with the observation that since the 1960s, agricultural production

systems have become much more complex as a result of what Rabbinge (2008) has referred to as five megatrends in agricultural production: 1) a significant increase in land and labour productivity; 2) a broadening of goals and objectives for the agricultural sector through concerns for rural livelihoods, the environment, landscapes and animal welfare; 3) a shift from small-scale craft-type production to large-scale industrial production systems; 4) the emergence of complex, global agri-food chains; and 5) a growing concern for food quality and safety, and health. These more complex agricultural production systems require more advanced innovation systems to generate, adapt and disseminate more advanced technologies and management and production practices.

The internationalisation of R&D and innovation, discussed in the industrial sector by Niosi (1999) and the agricultural sector by Byerlee and Fischer (2002), the emergence of more interactive forms of innovation as represented in Leydesdorff's (2005) triple-helix model and Chesbrough's (2003) open innovation model and the arrival of new actors such as the international seed and life sciences companies in agricultural innovation in Asia (Parayil 2002) explain why a larger number of actors are involved in more complex interaction patterns.

A key reason for linkages being problematic is that as agriculture innovation in Asia has moved from the traditional green revolution model to new, more complex paradigms, it is increasingly difficult to develop, fund and maintain the linkages that are so necessary for innovation. Traditionally, public RTOs played a central role, especially in the green revolution paradigm. However, each of the succeeding three paradigms introduced herein is quite different from the green revolution with regard to actors, technologies and institutional aspects. Following Powell and Grodal (2005), it is argued that each of the four innovation paradigms is characterised by its own network type and sets of linkage types.

Networks in the green revolution paradigm can be referred to as organisational networks, as they are structured around a number of well-established public agricultural research organisations. They are characterised both by overembeddedness and underembeddedness (Uzzi, 1997), with the latter the more severe problem because of ineffective relationships with extension organisations, farmers, processors and retailers. Neither cooperation nor competition works particularly well in this model, due respectively to the compartmentalisation of public sector organisations and the lack of incentives to produce high-quality technologies that address the needs of farmers. The agricultural research councils that have been established in a number of countries (e.g., Sri Lanka and Pakistan) to integrate the different stakeholders are not working well, as their participation is limited to a narrow range of public sector research actors.

Networks in the sustainability paradigm can be seen as community-of-practice (CoP) networks—organised from the bottom up and based on relatively informal arrangements. They involve a broad range of actors including farmer groups, NGOs and sometimes private or public R&D actors and others in the chain. CoP networks integrate organisations with a deep understanding of producer problems

and environmental issues, local production systems and technologies. Linkages between these actors are however often complicated because of different interests, objectives and agendas.

Private sector seed and biotechnology companies are seeking new markets and increasing their level of investment in developing country agriculture, especially in Asia. They structure their networks through strategic alliances and partnerships with other companies and reach technology users through their marketing departments. They have very few linkages with either public research organisations or local communities—although they sometimes try to reach them through corporate social responsibility programs.

Retail chains and agri-food chain networks play a growing role in agricultural innovation in Asia. They are transferring new production technologies and standards throughout the agri-food chain to upgrade production systems and to ensure reliable supplies of high-quality products for their processing and/or retail operations. They play a key role in reorganising the supply chain by establishing regional distribution systems and direct relationships with producers through contract farming arrangements and the introduction of quality standards.

Conclusions and Recommendations

Effective linkages between actors are a key requirement to promote innovation. At the same time, their lack represents a key weakness in many agricultural innovation systems in Asia and developing countries in general. Building networks of relevant actors requires vision, funding, skills and commitment—all of which are in short supply, explaining why linkages are so often absent.

Two common situations where network failure occurs are related to the under-embeddedness or overembeddedness of actors in networks (Uzzi, 1997). Overembeddedness refers to very tight integration among a small group of actors at the expense of a broader set of linkages. This represents the traditional national public agricultural research system in Asia, which is formed by a closed group of public research institutes with limited interactions with other public and private actors. From the broader sectoral innovation system perspective, in Asia, the opposite situation, underembeddedness, is the rule: crucial linkages are missing, which could generate, adapt and transfer new agricultural technologies and management practices.

Although linkages are in short supply, the demand for them is exploding as innovation systems become more complex. For these two reasons, public agricultural research organisations in Asia no longer play the central role in agricultural innovation that they did during the green revolution.

Agricultural RTOs have traditionally focused on conducting in-house research rather than engaging with other innovation actors, which explains the low priority and funding for linkages. The general recommendation for public agricultural RTOs

is that they need to improve their capacity to link with other innovation actors. More specifically, the following four recommendations are made.

- At the policy level, it is important for Ministries of Agriculture and other research funding agencies to ensure that research plans are appropriately embedded in agricultural and rural development plans and innovation strategies. To enable public actors to work together more effectively, Ministries of Agriculture need to reduce compartmentalisation and fragmentation within and between public sector actors in the agricultural innovation system by integrating much more closely agricultural research, extension and education functions.
- To enable private and civil society actors to work together more effectively, it is of key importance for policy makers to provide an effective institutional framework and for RTOs to provide the right incentives to engage in linkages. Not only do linkages require operational budgets for communication, travel and meetings (which are usually in very short supply), more importantly, researchers should also be encouraged to engage with other actors, and be rewarded for it. It is important to recognise that working with other organisations is inherently risky—and that such risk taking should be rewarded rather than punished.
- Most public RTOs have highly centralised decision-making processes. However, working with other organisations cannot be managed from the top. It requires the decentralisation of decision-making authority and a budget for linking with external parties. Experimenting and learning with other organisations requires horizontal decision making.
- To promote innovation and to ensure positive development outcomes, it is important for policy makers and public sector RTOs to participate in modern biotechnology and agri-food chain networks and to ensure that technology users, including (small) farmers and processors, are effectively involved in such networks.

NOTES

1. This depends very much on the sector or the technology. Traditionally, most agricultural knowledge was in the public domain, and the free sharing of genetic materials was the norm. With the modern biotechnology revolution, however, intellectual property is now vigorously protected by patents.
2. The Indonesia Agency for Agricultural Research and Development (IAARD), the Pakistan Agricultural Development Council (PARC) and the Sri Lanka Council for Agricultural Research Policy (CARP) are examples.
3. This is especially so because the sample of organisations and individuals interviewed was biased in favour of collaboration. Contacts were made through the public agricultural research organisation and focused on partner organisations with whom some level of familiarity and contacts already existed. This is consistent with the findings of Spielman et al. (2007), who conclude that the same issue of partnership problems applies to international agricultural research centres, even though international centres are much better funded than are national research organisations.

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