A comparative analysis of agricultural research and extension reforms in China and India

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Abstract

Purpose – There is growing interest from the global development community in the role of agricultural research and extension (AR&E) systems to achieve development targets. Despite this interest, many smallholders in developing countries continue to lack access to updated agricultural information and reliable services. In an effort to increase the effectiveness, impact, and reach of AR&E programs, many governments have attempted to reform their national systems. The paper aims to discuss these issues.

Design/methodology/approach – This paper systematically compares the systems and reforms of AR&E in China and India in order to draw out lessons applicable to developing countries. This paper first reviews the existing literature on AR&E systems and their role in agricultural and economic development. The authors then provide a detailed review and comparative analysis of the reforms and approaches implemented in the AR&E systems of China and India. The authors apply this comparative analysis to draw out lessons that can be applied to inform the reformation of AR&E systems in developing countries.

Findings – The authors find that although both countries face similar agricultural development challenges, each took a different approach in the reformation of AR&E to address these challenges. Each country's approaches had different impacts on the effectiveness of the system. Lessons from the reformation of the AR&E systems in China and India can be used to inform and improve the impact of AR&E in developing countries.

Originality/value – The paper examines two systems together using a set of common indicators and factors. The paper's value comes from its usefulness in informing future AR&E reforms in other developing countries in order to increase the impact of these reforms on development outcomes.

Keywords China, India, Comparative analysis, Agricultural research, Agricultural extension services, Policy reform

Paper type Research paper

1. Introduction

The rapid globalization of national and international agriculture systems presents a multitude of challenges for researchers, extensionists, and policymakers in developing countries (Birner *et al.*, 2009; Labarthe *et al.*, 2013). Over the past several decades, China

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and India have implemented numerous reforms to increase the ability of agricultural research and extension (AR&E) to drive agricultural development and economic growth (Babu and Joshi, 2014; Fan and Gulati, 2007). However, the success and impact of these reforms on agricultural development has varied. China and India took very different approaches to tackling agricultural development issues. China adopted a bottom-up approach beginning with reforms within the agricultural sector. In contrast, economic growth in India has been compelled by top-down reforms. Thus far, the agriculture-driven economic growth in China had a greater impact on reducing poverty, particularly in rural areas (Huang and Rozelle, 2010).

It is well recognized that AR&E play central roles in increasing agricultural productivity in developing countries (Huang and Rozelle, 2010). Agricultural research and the dissemination of up-to-date information through extension has enabled China to increase rural household incomes and transform the agricultural sector (Chen *et al.*, 2012; Fan *et al.*, 2006). Although China and India are still characterized by the typical features of a developing country (e.g. low average per capita income, majority of households dependent on agriculture), both countries have become success stories for agricultural development and transformation. This paper seeks to investigate and compare the measures taken to reform the AR&E systems in the two countries. Through this comparison, we aim to draw out key lessons to AR&E in developing countries.

The rest of the paper is organized as follows. The remainder of this section reviews literature on the various challenges facing national AR&E systems, and the reforms approaches used to address these challenges. Section 2 highlights the salient features of the national AR&E systems in China and India, and the unique challenges currently facing these systems. The Section 3 presents a comparative analysis of the reforms and performance of agricultural research in the two countries. Similarly, the Section 4 compares the extension systems of China and India, and draws out lessons applicable to the reformation process in developing countries. Section 5 highlights challenges in linking the findings of agricultural research with extension delivery in the two countries. Concluding remarks including policy recommendations are provided in the last section.

In analyzing the reforms of research and extension systems researchers have focussed on the following specific indicators: relevance, efficiency, effectiveness, equity, sustainability, and impact (following OECD, 1991, 2011). The relevance of an agricultural research or extension system is determined by the system's ability to address the technical and advisory needs of farmers, particularly smallholders. The efficiency of AR&E systems refers to the ability of the system to provide the intended benefits at the lowest possible cost, in terms of both money and time. Effective AR&E systems are critical to sustainable agricultural development (Umali and Schwartz, 1994; Swanson, 2006). Extension information should be coupled with appropriate incentives for farmers to adopt and manage the new technology or practice (Anderson and Feder, 2004; Pal and Byerlee, 2006). An effective extension system may address gaps in the technical assistance given by other providers, thereby increasing the level of equity in the delivery of extension services. The sustainability of a research or extension system depends on its ability to maintain its relevance to meet the needs of farmers.

The existing agricultural technology and knowledge are not sufficient to meet the expansion in food production needed to meet the set development targets (Bishwajit, 2014; Rosegrant *et al.*, 2007; Reeves *et al.*, 1999). In order to increase agricultural production and efficiency, new technologies, and practices must be developed and subsequently disseminated to farmers. The development and diffusion of a new technology is ultimately dependent on the efficiency and effectiveness of the AR&E

systems (Eicher, 2001). Many developing countries have recognized the central role of research and extension in order to use agriculture as an engine of pro-poor growth and sector transformation (Rivera and Sulaiman, 2009; Birner and Anderson, 2007). Agricultural transformation requires smallholders to shift away from traditional production methods, thus increasing the need for a more diversified extension system and a more responsive research system (Birner *et al.*, 2009; Hu *et al.*, 2012b; Umali and Schwartz, 1994). However, information on how to produce, process, and market commodities remains inaccessible to a large number of smallholder farmers in the developing world (Babu *et al.*, 2013). China and India have varied in their efforts to reach smallholders through AR&E.

It is important to note that AR&E operate within a wider innovation and knowledge system. Agricultural innovation and knowledge systems connect farmers and institutions to "promote learning and to generate, share, and use agriculture-related technology, knowledge, and information" (Rivera *et al.*, 2001; Labarthe *et al.*, 2013). This system includes farmers, extension agents, agricultural researchers, and educators, enabling them to harness knowledge from various sources to improve farming and livelihoods (Rivera *et al.*, 2001; Labarthe *et al.*, 2013). Cooperation between research, extension, and universities will not only use resources more efficiently, but will increase the return on investments made in all three areas (World Bank, 2012; Eicher, 2001). Investments in individual capacity at the university level will lead to greater returns in research productivity, and therefore will lead to increases in the quality of extension.

Major global developments shape the role of extension and drive the need for reforms (Qamar, 2005). Agricultural research systems in developing countries continue to confront new challenges, such as food security, climatic concerns, natural resource constraints, and land use issues (OECD, 2010). These challenges hinder the impact of agricultural research on the livelihoods of smallholder farmers. To overcome these challenges, agricultural research systems will have to rethink their management of funding, knowledge, and organizational and human capacity. Similarly, agricultural research in India has suffered due to organizational challenges, unfocussed research priorities, and weak linkages between research developments and extension delivery (Bishwajit, 2014).

Agricultural extension systems in developing countries continue to face numerous constraints that undermine the delivery of quality services and information to smallholders. Common challenges in extension delivery include wide dispersion of poor farmers, varied information needs of farmers, and inadequate financial support for extension agencies (Ferroni and Zhou, 2012a). In China, further market reforms have been introduced, such as increased commercialization, which has resulted in many smallholders being unable to access services (Hu *et al.*, 2012b). As agricultural extension delivery in India has become more pluralistic, a greater level of coordination is required. Although India's innovations in agricultural extension organization have increased farm incomes, efforts to scale-up these innovations have been severely constrained by a lack of government resources, limited support for local extension programs, and a lack of partnerships with NGOs to organize farmers' groups.

Research system reforms are a key strategy for increasing the productivity of research investments in several developing countries (Jin *et al.*, 2005). The key objective of such reforms is to move away from a research system that is largely supply-driven, poorly capacitated, unfocussed in its priorities, ineffective in its development of useful technologies, and poorly integrated with other elements of the agricultural knowledge system (You and Johnson, 2008). Reformed research systems aim to be dynamic, effective, and impact-oriented. Improvements and investments in agricultural extension and advisory services coupled with progress in agricultural research have the potential to improve farm-level productivity, thereby increasing the incomes of rural households (Benson and Jafry, 2013; Labarthe *et al.*, 2013). While the investment in research has shown to be beneficial in reducing poverty (Fan *et al.*, 2009), further reforms are needed to improve the productivity of agricultural research systems. Several significant innovations have been made to improve the delivery of extension services. However, the impact of extension on small- and medium- size farmers has been mixed due to varied quality in the content, delivery, and access to services.

The agricultural sectors of China and India are highly diversified in terms of both production environments and activities. Both countries have seen significant agricultural achievements including increased productivity and reduced poverty. However, there is room for significant improvement. Table I provides a broad comparison of the basic indicators of agricultural development in China and India. As is illustrated below, small farms (<2 ha) make up a vast majority of farming households in both countries.

In both countries, a variety of reforms have been implemented in an effort to address specific institutional constraints that limit the effectiveness of the existing AR&E systems in meeting agricultural and rural development goals (Swanson and Rajalahti, 2010). In the early 1970s, agricultural policy reforms were undertaken to reach smallholder farmers and address poverty reduction targets. Although the training and visit (T&V) extension model had success in promoting adoption of Green Revolution technologies, it failed to have the intended impact in areas where the technology did not match the needs of farmers (Babu and Joshi, 2014). The effectiveness of the T&V approach was limited as extension messages and practices were often designed with little input from farmers, highlighting the need for reformed approaches to extension design and delivery (Ferroni and Zhou, 2012b).

Many developing countries have implemented pluralistic extension systems in which the delivery of extension services are contracted out to private sector actors such as NGO's, private companies, and farmers' cooperatives (Rivera *et al.*, 2001). Pluralism creates an opportunity for both public sector reforms and private sector development, but requires effective coordination among key institutions (Umali and Schwartz, 1994). Many developing countries are increasingly privatizing extension services previously provided by public institutions due to decreased government budgets and efficiency. In the instance of total privatization, extension services are funded and delivered

Indicator	China	India
Rural population (million)	635.69	851.53
Rural population (% of total)	47	68
Rural poverty rate (%)	8.5	25.7 (2011 est.)
GDP per capita (current USD)	6,807.4	1,497.5
Employment in agriculture	31.4	47
Smallholder farmers (less than two hectares) (%)	97.5 (2006 est.)	85.9 (2006 est.)
Cultivated land (% of land area)	52	60.3
Irrigated area (% cultivated land)	52	35.2 (2010 est.)
Fertilizer consumption (kg per hectare of arable land)	485.7	163.7
Agriculture, value added (% GDP)	10.0	18.0

Sources: World Development Indicators (2014), FAO (2012), Zhou (2010), National Bureau of Statistics of China (2014)

Table I.
Broad comparison of agriculture in China and India in 2013

entirely by private sector actors. A number of countries have decentralized their agricultural extension system to transfer of authority from the central government to lower tiers of government. Subsidiarity, an alternative reform approach, refers to the delegation of responsibility to the lowest level possible, such as farmer- or NGO-led extension programs. Subsidiarity creates an opportunity for the participatory approach aimed at increasing production and improving the quality of life in rural communities (Axinn, 1998).

2. Characteristics and challenges of AR&E system reforms in China and India

Before we can compare and analyze recent agricultural reforms in China and India, it is important to recognize the salient features of the national research and extension systems in each country. Tables II and III summarize the fundamental characteristics of each country's national agricultural research system (NARS) and national agricultural extension system, respectively. The following tables include the goals and mandates of the research and extension systems; the institutional architecture; the central institutions and/or key organizations; the primary investments which fund the system; the level of human capital in the system; and the linkages to other allied systems.

2.1 Characteristics of AR&E systems

Table II summarizes the salient features of the NARS in China and India. China's agricultural research system has grown to be the largest and most decentralized in the world. The national system was originally founded to promote domestic agricultural production to meet national food security needs (Huang and Rozelle, 2014; Chen *et al.*, 2012). There were 1,215 agricultural research institutes and 67 agricultural universities with over 55,000 full time equivalent research staff in China in 2013 (Ministry of Science and Technology (MOST), 2014). Public research institutes continue to form the majority of the agricultural research system, despite the rapid emergence of other types of research institutions (Fan *et al.*, 2006). There were 1,075 agricultural research institutes under the agricultural department, among them, 59 research institutes were directly under the MOA, 458 institutes and 558 institutes were managed by provincial and prefectural government, respectively (MOA, 2013a, b). Compared with local research institutes, national research institutes focus more on basic research and applied research that address key national priorities and challenges. The main work of provincial academies is applied research in the context of the local agroecological conditions, while prefecture level research institutes are primarily responsible for extension work (Lin, 1998). The agricultural research institutes are institutionally separated from education. Most of the agricultural universities or colleges are under the administration of the provincial department of education, and some key agricultural universities are under the jurisdiction of Ministry of Education. The focus of agricultural research in China has long been dominated by crop research. Most funds are allocated through five-year plans with supplementary funding for special issue arising during the period. Science and Technology (S&T) plan are divided into many kinds of S&T programs according their objectives. At the national level, Ministry of Science and Technology (MOST) is responsible for allocating the S&T funding to agricultural ministry and other ministries and national agencies. Project funds have been increasingly allocated through competitive funding mechanisms (Huang *et al.*, 2003; Fan *et al.*, 2006).The National Natural Science Foundation and National Social Sciences Foundation and other government funding agencies are allocated their funds based on peer reviews (Fan *et al.*, 2006). Funding mechanisms at provincial and prefectural levels parallel those at the

Characteristics	China	India
Goals/mandates	Push national agriculture production to meet national food security needs	Increase agricultural production to achieve national food security To plan, undertake, aid, promote, and coordinate education and research and their applications to agriculture and allied sectors
Institutional Structure	Publicly dominated system Highly decentralized in terms of management and funding Research institute dominated system Crop (e.g.) grain-oriented system Nearly completely organized by the government	Follows the Agricultural Research Council model (FAO), centered on Indian Council on Agricultural Research (ICAR)
Main institutions	Ministry of Agriculture Chinese Academy of Agricultural Sciences (CAAS) Chinese Academy of Tropical Agriculture Eight national agricultural universities Provincial Academy of Agricultural Sciences Provincial agricultural universities Emergence of other types of research institutions, including: Development firms owned by public agricultural research institutes Agri-business firms owned by governments Shareholder companies Domestic companies Multinational companies	Ministry of Agriculture, Department of Agricultural Research and Education (DARE) ICAR– advisory, funding, and coordinating council State Agricultural Universities (SAUs) All India Coordinated Research Projects (AICRPs) Krishi Vigyan Kendras (KVKs) – farm science centers
Investments	Largely funded by public investment Largely through competitive funding Rigorous investments in biotechnology and conventional technology Recent increased investment by private companies	Block grants from central government to ICAR and SAUs, determined by five-year plans Competitive funding at national and state levels Increased private sector development Increased role of private non-profit organizations Bilateral donors and international organizations
Human capital	55,061 full time equivalent (2012) 1,215 agricultural research institutes and 67 agricultural universities (2013)	9,328 in SAUs and 4,616 in ICAR institutes 100 ICAR institutes, 70 agricultural universities
Agriculture research – extension linkages	Linkages between research and extension are weak Township extension stations (TATES) County agro-technical extension centers (CATECs)	Created ATMA to integrate KVK research activities with district level programs and staff Farm Information and Advisory Centers (FIACs)

Sources: Huang and Rozelle (2014), Swanson and Rajalahti (2010), Huang *et al.* (2003), Pal and Byerlee (2006), Chen *et al.* (2012), Swanson (2006), Fan *et al.* (2006), ICAR (2015)

Table II.
Salient characteristics of research systems in China and India

Characteristics	China	India
Goals/mandates	National food security, focus on grain and major livestock Technology transfer	National food security Technology transfer National self-sufficiency? In staple crops?
Institutional Structure	Highly decentralized to township but recently shifted personal management and funding from township to county government Mixed results of previous structural reforms Most recent reforms separate public extension and commercial activities	Publicly dominated Pluralistic providers Increased participation from private sector and NGOs
Main institutions	Ministry of Agriculture National Agricultural Technology and Service Center Public agricultural extension system (PAES) PAES stations, organized by agricultural sub-sector County agro-technical extension centers (CATECs) and its sub-station at district or township levels	Ministry of Agriculture (MOA) Line Departments: Department of Agriculture (major field/staple crops Department of Animal Husbandry Department of Fisheries Indian Council for Agricultural Research (ICAR) Agricultural Technology Management Agency (ATMA) State Agricultural Universities (SAUs) National Institute of Agricultural Extension Management (MANAGE) State Department of Agriculture (DOA) Krishi Vigyan Kendras (KVKs) – farm science centers Agri-clinics and Agri-business Centers (ACABC) Agricultural Technology Information Centers (ATICs) National Agriculture Technology Project (NATP)
Investments	Recently, increased financial support from the government Government investment includes: Operating budget Project grants Capital construction (e.g. buildings, instruments) Training	Prior to NATP, all money came from central government as earmarked for extension activities (e.g. irrigation or fertilizer technologies) NATP decentralized funding by giving it directly to semi-autonomous ATMAs, approved by the local farm advisory committee (FAC)
Human capital	700,000 staff (estimated in 2010)	91,288 posts filled (2011)
Linkages to agricultural education, nutrition?	Deemed agricultural universities	Courses for future extensionists through SAUs Both ICAR and the Central Agricultural University (CAU) are under the control of DARE

Sources: Huang and Rozelle (2014), Glendenning *et al.* (2010), Hu *et al.* (2012), Sulaiman (2012), Swanson and Rajalahti (2010)

Table III. Characteristics of the agricultural extension systems in China and India national level. Private R&D investment increased rapidly since 2000 and was about 17 percent of total agricultural R&D in 2006 (Hu *et al.*, 2011).

Public research entities in India consist of two parallel systems. First, the central level comprises of the Indian Council of Agricultural Research institutes and their respective regional stations across the country. State level research comprises of deemed State Agricultural Universities (SAUs) and their regional stations across the respective states. Indian Council for Agricultural Research (ICAR) is an apex body at the national level for coordinating, guiding, and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country with the more than 150 research entities. The Council was established to play a central role in shaping the national research system by setting national and state research agendas (Mruthyunjaya and Ranjitha, 1998). There are eight technical divisions within ICAR including crops, horticulture, animal science, fisheries, natural resource management, engineering, education, and extension. ICAR established Krishi Vigyan Kendras or KVKs at the district level that are responsible for the transfer of new technology and the training of local Farm Science Center (Swanson and Rajalahti, 2010).

In an effort to promote multidisciplinary research ICAR implemented the All India Coordinated Research Projects (AICRPs), which promote research collaboration across institutions. Within the Ministry of the Agriculture there is a designated Department of Agricultural Research and Education (DARE) aimed at providing the necessary linkages between the government and ICAR. In terms of funding, public investment in agricultural research in India comes almost entirely from the central government and is allocated to ICAR and the SAUs. Funding from the government comes in the form of block grants, which are determined by five-year plans. Competitive funding for research projects is also available at the national and state levels. Private investment in agricultural research in India is growing, but needs to be improved. The central government aims to promote private sector investment in agricultural research and development through financial incentives such as tax exemptions (Pal and Byerlee, 2006). In terms of capacity, ICAR currently coordinates the efforts of over 100 research institutes and 70 universities. In terms of human capital, it is estimated that ICAR employed 4,484 total scientific staff in 2014 (ICAR, 2015). In India, the NARS and agricultural universities employed a total of nearly 14,000 scientific staff. The innovations of agricultural research are linked to extension service delivery through the KVKs transfer local research and technologies to farmers.

Table III illustrates the distinctive features of the agricultural extension systems in China and India. The agricultural extension system in China aims to achieve national food security through increased production. Although the results of previous structural reforms have been mixed, the most recent reforms include the separation of extension and commercial activities within the public agricultural extension system (PAES). Agricultural extension services are delivered through county agro-technical extension centers (CATECs) and township agro-technical extension stations (TATES), which serve as grassroots extension institutions. Government investment in the PAES comes in three distinct forms: operating budget, project grants, and capital construction (Hu *et al.*, 2012a, b). The operating budget is used to cover office expenses, salaries, and extension activity costs.

China's agricultural extension system is the largest in the world, with an estimated staff of 700,000 in 2010 (Huang and Rozelle, 2014). The system is highly decentralized, with over 75 percent of government agricultural extension organizations at the township levels (Zhong, 2014). Presently, the public agricultural technology extension system operates at five levels: national, provincial, city (or prefectural), county, and township. The extension system is becoming more pluralistic as the number of non-profit and private extension organizations providing services increases. Similar to agricultural research, the funding for extension services comes almost entirely from the government. Extension activities in China are linked to agricultural education through pre-service courses offered through the agricultural universities. In addition, in-service training is offered to extension professionals through any of the hundreds of agricultural technology extension and service centers around the country.

Agricultural extension in India aims to help achieve national food security and self-sufficiency in the production of staple crops (Swanson and Rajalahti, 2010). A number of institutions are involved in the management and delivery of extension services in India as the system becomes increasingly pluralistic (Pal and Byerlee, 2006; Swanson, 2006). The mandate of the Indian Council for Agricultural Research (ICAR) is to plan, undertake, aid, promote, and coordinate education and research and their application to agriculture and allied sectors (Swanson and Rajalahti, 2010; Glendenning *et al.*, 2010). The Council manages extension activities through KVKs or farm science centers at the district level and through the SAUs at all levels. Public extension services are managed and implemented at the state level through the state's Department of Agriculture (DOA). The Agricultural Technology Management Agency (ATMA), which works under the umbrella of the Ministry of Agriculture, was formed to strengthen the linkages between AR&E. The design and implementation of the ATMA will be discussed in a later section.

2.2 Common challenges in research and extension systems in China and India

Table IV highlights the major challenges of the national research and extension systems in China and India in reaching agricultural development goals. As illustrated, the two countries share similar challenges in the areas of relevance and impact of the national systems' research and extension efforts.

Through the broad description of the AR&E systems in China and India above, we can see that although their national systems are aimed toward similar agricultural development goals, both countries have structured their systems quite differently. The organization and management of each country's national system have had varying impacts on the effectiveness and efficiency of AR&E efforts. In the next sections, we will examine the organization and capacity of each system in more detail, to draw out lessons learned from each country's unique experience. The next section will compare the agricultural research systems, while Section 4 will do the same for extension.

3. Comparative analysis of the agricultural research systems and reforms in China and India

Agricultural research has been recognized as a major contributor to poverty reduction, productivity gains, and agricultural innovation across the globe for its critical role in the development of agricultural technology (Stads and Rahija, 2012; Huang and Rozelle, 2010). The Green Revolution in the 1960-1980s had a significantly positive impact on rural incomes and food security across Asia. However, the effects of this phenomenon have begun to level off, raising the need for the revival of the agricultural sector. Effective agricultural research has a central role to plan in the increased agricultural development of the region (Beintema and Stads, 2008). This section compares the structure, funding, and capacity of the agriculture research systems in China and India. Table V provides some basic indicators of agricultural research in India and China.

Table IV.
Common challenges in research and extension systems

Challenges	China	India
Management	Lack of coordination between institutions Structural separation of agricultural research and education Duplication of research activities	Lack of coordination between research institutes at different levels or on different focus areas Center vs state roles (e.g. central government institutes and ICAR institutes vs state government and SAUs)
Capacity	Research: relatively low number of highly trained scientists at provincial level Extension: low capacity of local extension workers, difficult to hire youth or able persons	Low capacity of village-level extension workers Limited technical capacity at central level, and management capacity at local levels
Reach/impact	Takes on basic as well as applied research and development of technologies (some of this could be done by the private sector) Pilot inclusive agricultural extension program could help increase farmers' access to extension services	Balancing multiple research objectives Limited responsiveness to emerging issues/challenges
Funding	Research: despite significant rise in funding, low share of core funding, large duplication, and excess burden of retired staff Extension: largely funded by local government, difficult in the poor regions	Top-down funding mechanisms from the central government inhibits the effective utilization of the ATMA model Sustainability of research funding.
Relevance	Research: system does not respond appropriately to farmers' changing demands for technologies but academic papers and own promotion Extensi: difficult to meet farmers' diversified demand for technology and market information service	Services do not meet the diverse information needs of farmers, particularly smallholders.

Sources: Huang and Rozelle (2014), Swanson and Rajalahti (2010), Huang *et al.* (2004), Pal and Byerlee (2006), Fan *et al.* (2006), Glendenning *et al.* (2010)

3.1 Agricultural research in China

Due to the growing demands placed on NARSs, it is increasingly important that institutional innovations are implemented to improve research system management and organization (Mruthyunjaya and Ranjitha, 1998). In a country such as China where agriculture is dominated by smallholders, the role of agricultural research in increasing productivity is even more critical (Huang and Rozelle, 2010).

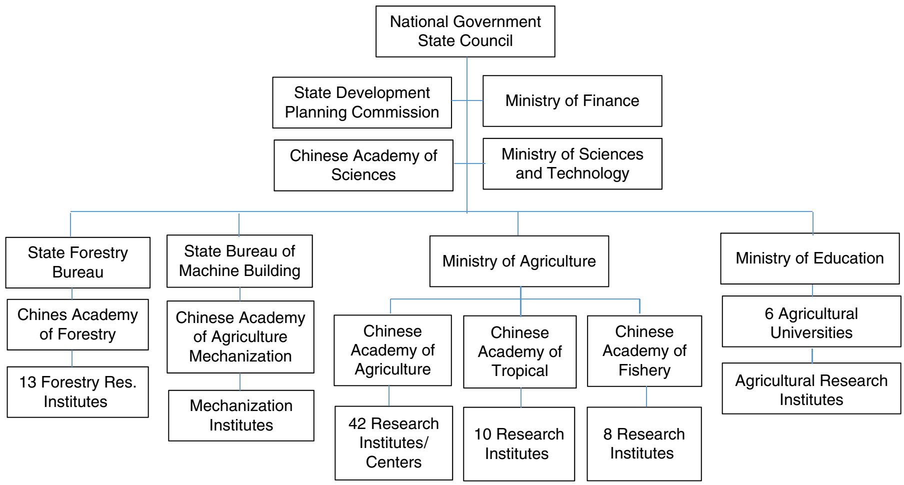
3.1.1 Reformation of the agricultural research system in China. The current structure of the agricultural research system in China is illustrated in Figures 1 and 2. The organization at the national and lower levels is relatively similar. At all three levels, agricultural research efforts are managed by the government. To adapt the changes of economic environment and more responsive to the needs of agricultural development, agricultural research system in China has undertaken several substantial reforms aimed to make agricultural research more demand-driven so that the system can be more responsive to market needs.

China started its first agricultural research reform through changing its financing arrangement in the mid-1980s. Before this reform, the government provided all of the

Particulars	India	China
I. Agriculture		
1. Share in total GDP in 2013-2014 (%)	13.9	9.4
2. Share in Employment in 2011-2012 (%)	48.9	31.4
3. Cereal production in 2013-2014 (million tons)	245.5	552.7
II. Major challenges facing agriculture		
1. Targeted growth rate per annum (%)	4	4
2. Average landholding size(ha)	2.83 ha in 1970-1971 to 1.16ha in 2010-2011	0.6 ha per rural household in 2013
3. Number of smallholders (millions)	193 (2010 est.)	93 (2010 est.)
III. Agricultural Research		
1. Expenditure share of research and education in total AgGDP in 2011-2012 (%)	0.76	0.69 for agri research in AgGDP in 2009; 3.87% for education total GDP in 2013 (no data for agri education)
2. Total scientific staff working in NARS in 2010-2011 (in numbers)	13,944	70,711
3. Total number of research entities in 2010-2011(in numbers)	321	1,215
4. Private sector contribution	About 500 seed companies and spend their 10-12 % of their annual turnover in research	R&D expenditure from the private sector has risen from 3 percent in 1995 to over 16 percent in 2006 (Hu *et al.*, 2007)

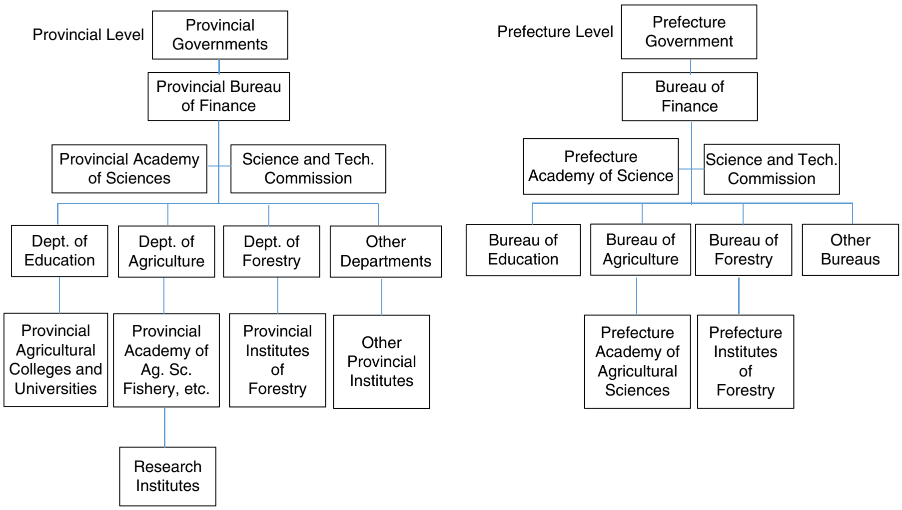
Source: Authors' compilation

Table V. Comparison of Indian and Chinese agricultural research systems



Source: Huang *et al.* (2003)

Figure 1. Organization of agricultural research in China at the national level



Source: Huang *et al.* (2003)

Figure 2.
Organization of agricultural research in China at the provincial and prefecture levels

funding for research. Most of the funds were allocated on a formula basis to the research institutes. After mid-1980s, research project funding has been gradually shifting to competitive grants while core funding remains on formula basis. In addition, accompanied with gradual liberalization of China's agricultural market and insufficient resource to finance the huge size of public agricultural R&D system, government encouraged public research institutions to commercialize their research outputs or technologies in the late 1980s and the early 1990s, allowing the institutes to support themselves financially (Fan *et al.*, 2006; Huang and Rozelle, 2010). According to the official report, the revenue of agricultural research institutes from the commercial activities accounted for 46 percent of the total budget in 1999 (Huang *et al.*, 2003). However, the impacts of the reform were mixture. Although the real income from commercial enterprises increased, only a small amount of that income was used to fund research and commercial income was also insufficient to support rising salaries for both exiting and retired staff. On the other hand, while competitive grant funds had shifted resources to the better scientists, funding for agricultural research projects in real terms declined. In fact, many of the commercialization by public agricultural research institutes has had little relationship to the technology they were responsible for developing (Huang *et al.*, 2003; Huang and Rozelle, 2010; Fan and Gulati, 2007).

The second round reform was implemented in the late 1990s, which attempted to separate the types of research institutes into those that are commercializable and those that are more applied-basic and basic research. Increased public funding mainly invested in those left in the non-commercial sector. While for those belonged to commercialized research institutes, government's funding was either capped or decreased, their revenues had to largely depend on commercial income. While the reform was essential for having a demand-driven agricultural research system and enhancing the existing public research institutions, the challenges were more than the reform promised. The most common problem was that the institutes that were supposed to begin to operate as an independent firm either failed or expected their failure and returned to government for assistance (Huang *et al.*, 2003; Fan and Gulati, 2007).

Given the experience and lesson learned from the previous reforms, a new set of agricultural research programs and reforms has been implemented since middle 2000s. First, agricultural research budget, including core funding, has increased substantially to enhance public research system and its innovation capacity. Second, to foster national and regional innovation capacity and meeting farmers' demand for technologies, China has launched a new funding system, the Modern Agricultural Industry (or Sector) Technology System, since 2008. This system includes 50 agricultural commodities (34 crops, 11 livestock, and five fishery products). For each commodity, it includes one National Center of Technological R&D and several Comprehensive Experimental Station in major production regions and focusses on key technologies and marketing issues related to this commodity. Research funding is guaranteed for each principal scientist in the system. Third, to further improve the innovation capacity and solve the week linkage between R&D and agricultural economy, with support from the Central government, Chinese Academy of Sciences has carried out Agricultural Science and Technology Innovation Program (ASTIP) since 2013. ASTIP is a new funding paradigm and aimed at generating technologies that can be rapidly applied to solving real production problems through supporting long-term and interdisciplinary research, capacity building, and research facilities. The last but not least, in 2013, the State Council issued an official document to improve innovation capacity in seed industry through a separation of major plant breeding programs (e.g. hybrid seeds) from public research institutions and providing scientists incentives (e.g. keeping public retirement benefit package) to join seed enterprises.

3.1.2 Expenditure on agricultural research. The amount of resources allocated toward agricultural research in China has more than doubled in the past decade. The pathways for funding agricultural research in China have undergone substantial reforms in recent years. Prior to the 1980s, the allocation of funding to research institutions was mainly based on the number of research staff rather than on performance (Chen *et al.*, 2012; Fan and Qian, 2005). In an effort to improve impact and performance, China began to reform its agricultural research system in the mid-1980s by shifting funding from institutional support to competitive grants (Huang and Rozelle, 2010; Fan and Gulati, 2007). Research institutes can obtain funding through competitive grants from government agencies at national level (e.g. the Ministry of Science and Technology, National Natural Science Foundation, Ministry of Agriculture, and other ministries) and similar government organizations at provincial level as well as international organizations and foreign agencies. The share of funding from competitive grants increased from zero to nearly 30 percent in 1998 and over 40 percent in 2006 (Huang and Hu, 2008). Accompany the reform of agricultural research system, the fixed R&D projects and operation budgets are kept increasing.

It remains a challenge to find good data on the total expenditure on agricultural research due to the number of governmental and research agencies involved in the funding process. Here, we focus on the R&D expenditure of agricultural research institutes and agricultural universities according the data available. The expenditure data included here only relates to research activities (funding for education has been excluded). China significantly increased its agricultural R&D spending after the turn of the millennium, ending a period of stagnation in the 1990s. In 2012, the total agricultural expenditure of agricultural institute and agricultural university were estimated at CNY 30 billion at current price, about CNY 23 billion to institute and CNY 7 billion to university. Agricultural expenditure increased very fast during last decade. The average real growth rate exceeded 13 percent, especially the investment in agricultural university has grown faster than the overall growth with near 20 percent annual growth rate during 2002-2012 (Ministry of Science and Technology (MOST), 2014, Ministry of Agriculture (MOA), 2013a, b, Ministry of Education (MOE), 2003-2013).

Similar to the recent trends in total agricultural research funding, both the R&D expenditure through research projects in institute and university increased rapidly, increased from CNY 1,850 million and CNY 511 million in 2002 to CNY 8,485 million and CNY 3,195 million in 2012 at 2005 constant price with 15 and 20 percent annual growth rates, respectively. The total R&D projects expenditure within universities and research institutes increased from CNY 2,361 million in 2002 to CNY 11,680 million in 2012 at 2005 constant price, and its annual growth rate reached 17 percent. The expenditure share of basic research was very small and was only about 7 percent, especially in the institute, less than 6 percent in 2002. However, both the expenditure on basic research expanded with the fastest growth rates in universities and institutes, which were over 30 and 20 percent of annual growth rates during 2002-2012, respectively.

There are also significant differences between the structures of R&D expenditure in universities and institutes. Universities spent nearly 60 percent expenditure on applied research, 30 percent expenditure on basic research, but only 6 percent on experiment development in 2012. However, institutes spent most of expenditure on experiment and development, about 20 percent to applied research, and less than 10 percent on basic research in 2012. Both agricultural R&D expenditure on institutes and universities in China are mainly funded by the central government. The shares of government funding were nearly 90 percent. The remainder of funding stemmed from foreign organizations and the commercial activities of individual institutes.

3.1.3 Capacity for agricultural research. In terms of the number of staff, China has the largest agricultural research system in the world (Huang and Rozelle, 2014). The capacity for agricultural research in China has been enhanced in recent years due to increased investments in both research and higher education institutes. About 70,711 research staff worked in research institute and agricultural university in 2012. Research staff in institutes accounted for about 70 percent and the remainder were employed by universities. The total staff increased by 16 percent (near 10,000 persons) during 2009-2012. In research institutes, nearly 40 percent of staff held advanced (masters or PhD) degrees in 2013, and about 60 percent of agricultural researchers and scientists work primarily on crops. Table VI illustrates the distribution of researchers across a wide variety of agricultural development topics.

Sector	Research personnel	PhD	MS	BS	PhD (%)	MS (%)	BS (%)
Farming, forestry, animal husbandry, and fisheries	50,528	6,432	13,746	19,878	12.73	27.20	39.34
Farming	30,119	3,307	8,440	11,859	10.98	28.02	39.37
Forestry	5,107	711	1,128	2,288	13.92	22.09	44.80
Animal husbandry	3,988	504	966	1,579	12.64	24.22	39.59
Fishery	2,330	386	690	811	16.57	29.61	34.81
Service activities for agriculture	8,984	1,524	2,522	3,341	16.96	28.07	37.19

Source: MOST, China Statistical Yearbook of Science and Technology (2014)

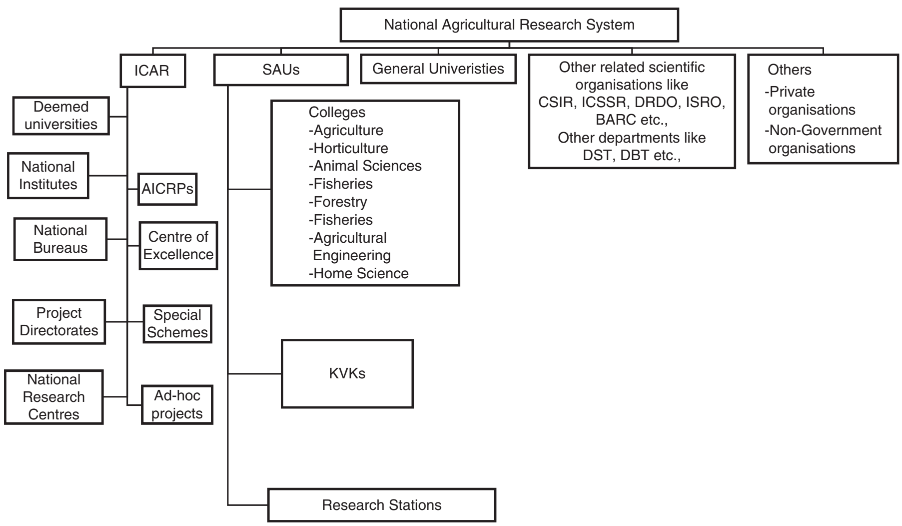
Table VI. Researchers in China agricultural research institutes by education in 2013

3.1.4 Current challenges. Despite the progress achieved, the structure of the research system has its own implications and challenges. Numerous ministries and agencies are involved in managing and conducting agricultural research. Thus coordination at the national, state, and local levels of various agencies continues to be a challenge. The current highly decentralized structure limits coordination and has led to funding efficiencies and duplications of research efforts and investment (Huang and Rozelle, 2014). At present, the central government has the power to both distribute state research funds and supervise their use, which in the past has led to the misuse of resources. In addition, more than one ministry may be involved in funding similar research and, due to the lack of a communication mechanism, some researchers use one project to apply for multiple funds from different sources. The MOST and MOF also launched several management reforms to strengthen top-level design, tackle segmentation and lack of coordination, develop a goal and performance-based evaluation system for the management of national science programs, and strengthen the ties between science and economy, and motivate researchers to the full extent. In a reform to be announced to curb academic corruption and encourage research innovation, the government will step back from managing the state research fund and hand over that power to a third-party agency. A third-party agency supervised by the government, such as the National Natural Science Foundation, will take over the power (Luo, 2014)[1].

3.2 Agricultural research in India

This section will examine the NARS in India. In order to provide a comparison to the Chinese system discussed above, we will examine the Indian system based on the structure, funding, and capacity of public research institutions.

3.2.1 Organization of the NARS in India. Figure 3 illustrates the structure of NARS including important links to education institutions. The public research system in India current consists of ICAR and its institutes along with the SAUs and their regional



Source: Authors' compilation

Figure 3. Organization of the national agricultural research system in India

institutes (Stads and Rahija, 2012; Pal and Byerlee, 2006). The structure of the agricultural research system allows for the integration of research efforts with extension programming, particularly through the KVKs or farm science centers. This structure enables the implementation of extension programs that are well-informed by relevant research. However, the separation of national institutes and special themes may limit the specificity of research programs. This may also limit the ability of research to set priorities based on the needs of smallholders. It is important that the organization of agricultural research enable the system to be responsive to the needs of farmers in a particular geographical area or farming system.

The research of the ICAR institutes covers a broad range of topics including crops, livestock, fisheries, natural resource management, agricultural engineering, and policy. However, the distribution of research institutes shows that it has major focus on agriculture (23 percent), animal science (19 percent), and engineering (19 percent) and very limited number of institutes are focussing on more specialized industries such as fisheries and horticulture. SAUs are mandated to perform state-specific research and education, following the US land grant system (Stads and Rahija, 2012). Many colleges on SAU campuses contribute to agricultural research including horticulture, agricultural engineering, animal science, etc. The large network of research institutes is funded and managed by ICAR. Research institutes include national institutes focussed on basic research and central research institutes focussed on commodity-specific research (Bishwajit, 2014). In addition to the institutes, ICAR manages the AICRPs which consists of multidisciplinary teams of scientists (Beintema and Stads, 2008). The AICRPs are housed on SAU campuses, and attract scientists from both ICAR institutions and the SAUs (Pal and Byerlee, 2006). In addition to the ICAR/SAU system, there are a number of non-agricultural universities and institutes that support or conduct agricultural research.

3.2.2 Public agricultural research expenditure pattern in India. The amount of funding allocated to research and the mechanisms that deliver this funding can be applied are powerful policy tools (Pal and Byerlee, 2006). Most public funding for agricultural research in India comes in the form of block grants. The amount of the block grants is determined by DARE five-year plan, which are developed for each ICAR institute. In view of the five-year plans, the government expenditure is classified as plan (which arise due to the plan proposals) and non-plan (spending during the year on routine functioning like salaries and overhead costs) expenditures. Funding allocations for SAUs follow a similar process, however, SAUs are funded in part by their respective states in addition to ICAR grants. Through this funding procedure, resource allocation decisions are made through an informed process that aims to address development objectives (Pal and Byerlee, 2006). There is some evidence that resource have shifted appropriately according changing production conditions (Pal and Byerlee, 2006).

Similar to recent changes in China's public agricultural research system, opportunities for competitive funding are increasing in India. Competitive funds are seen as a mechanism to increase the quality and accountability of agricultural research (Pal and Byerlee, 2006). This mechanism has also been recognized as a tool to direct funds to high-priority areas and specialized value chains.

The total expenditure on agricultural research and education in India presented in Table VII. Research spending was about six lakh crore rupees and constitutes about 0.9 percent of total GDP in 2010-2011. However, this is quite low in comparison to USA (2.8 percent) and China (1.7 percent) in 2009 (Department of Science and Technology

(DST), 2012). As illustrated by Table VII, total expenditure increased about 1.5 times from X plan (2002-2007) to XI plan (2007-2012). The pattern of expenditure indicated that the state and central budgets have nearly equally contributed to total agriculture research expenditure. The state's share (54 percent) was high in X plan and reversed (46 percent) in XI plan. It is important to note that the central government's expenditure on research has increased by 66 percent, while expenditure at the state level was about 22 percent during X and XI plans. The allocation of financial resources for research at the government and university levels has an impact on the effectiveness of agricultural research. It is important for funds to be effectively allocated toward basic and applied research, depending on the strengths of the institution.

Table VIII shows the expenditure pattern of ICAR over the years. As illustrated below, total expenditure has increased about 1.3 times during between X plan and XI plan. In addition, proposed expenditure under XII plan has almost doubled when compared to XI plan. These figures indicate that ICAR balanced spending on infrastructure development and long-term projects through plan expenditures and proper maintenance of non-plan expenditures.

Year	State	Center	RKVY	Total	Agriculture and allied GDP	Research/ education as % of AgGDP
Tenth plan	10,629 (54%)	9,102 (46%)	–	19,731	3,340,648	0.59
2007-2008	2,158	2,063	55	4,276	764,890	0.55
2008-2009	2,279	2,458	197	4,934	765,601	0.61
2009-2010	2,567	2,636	63	5,266	773,565	0.67
2010-2011	3,044	4,077	100	7,221	827,969	0.86
2011-2012	2,981	3,510	160	6,651	850,812	0.76
Eleventh plan	13,030 (46%)	14,745 (52%)	576 (2%)	28,351	3,982,837	0.70

Source: Planning Commission, Government of India (2013)

Table VII. Expenditure on agricultural research and education in India at 2006-2007 prices (in Rs Crore)

Year	Budget (at 2006-2007 prices) Plan	Non-plan	Total	Budget (at current prices)
X Plan	5,510 (55%)	4,470 (45%)	9,980	8,811 (4,900[a]+3,911[b])
2002-2003	916	915	1,831	1,449
2003-2004[c]	955	906	1,861	1,511
2004-2005	1,049	903	1,953	1,675
2005-2006	1,159	899	2,059	1,900
2006-2007	1,430	846	2,276	2,276
XI Plan	7,132 (55%)	5,951 (45%)	13,083	18,747 (10,120[a]+8,627[b])
2007-2008	1,306	822	2,129	2,337
2008-2009	1,428	974	2,402	2,960
2009-2010	1,263	1,077	2,340	3,261
2010-2011	1,462	1,815	3,277	5,173
2011-2012	1,673	1,263	2,936	5,016
XII Plan allocation	13,924	–	–	25,553[a]

Notes: [a]Indicates plan expenditure; [b]indicates non-plan expenditure
Source: Compiled by authors from various years of annual report of ICAR

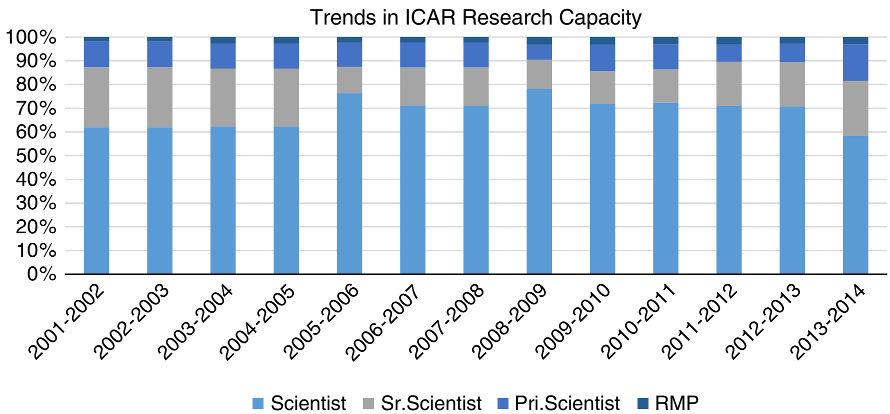
Table VIII. Expenditure of Indian council of agricultural research (in Rs crore)

3.2.3 Capacity for agricultural research. The regular production of quality agricultural graduates is critical to meet future agricultural development targets. SAUs as well as general ICAR deemed universities are the major suppliers of agricultural graduates in India. Stads and Rahija (2012) found that 43.1 percent of agriculture research staff in India were employed by higher education institutes, while 56.9 percent were employed by the government. In 2010, about 85,000 and 11,000 students were enrolled in Bachelors and Master's program, respectively, and about 600 students were awarded doctoral degrees (MHRD, 2010). Unfortunately, the agricultural research system is facing a growing shortage in human capacity, particularly in specialized areas. Approximately 43 percent of the SAUs and 28 percent of the ICAR posts were vacant in 2010. Vacancies in high level research positions has had severe implications on quality of research and teaching, and has ultimately lowered the quality of agricultural graduates produced. The distribution of researchers across the different types of research areas is currently unbalanced. In both ICAR and the SAUs, a majority of scientists are employed by general agriculture research followed by animal science research. Figure 4 illustrates that approximately 60 percent of ICAR staff are classified as junior scientists with mid-level scientists comprising nearly a quarter of staff. Senior scientists make up nearly 15 percent of staff, while research managers make up the remainder.

Table IX reveals that the number of ICAR research entities increased marginally during the end of the last decade and dropped slightly in 2014. Over the last decade, the composition of research institutions changed notably due to additional research funding and infrastructure by ICAR. During this period, agricultural universities have shown a continuous increasing trend in number and recorded about 50 percent growth.

3.3 Comparative analysis

Based on the analysis above, we are able to draw out some inferences from the structure, organization, and capacity of the Chinese and Indian systems of agricultural research. In terms of organization, the structure of China's agricultural research system could be reformed to promote coordination among institutes. While the organization of the system at the national level is mirrored at the provincial and prefecture levels, agricultural education and research remain disjointed, reducing the potential efficiency



Source: Authors' compilation

Figure 4.
Trends in ICAR research capacity: 2001-2002 to 2013-2014

of the system. In contrast, the structure of the Indian system, particularly the linkages between ICAR and the SAUs, integrates agricultural research, education, and extension efforts. The AICRPs on various themes and research challenges are good examples of a mechanism to promote coordination across institutions with different focus areas. Perhaps there is an opportunity to implement a similar mechanism in China. However, there is still room for improvement in both countries. In terms of funding, both countries suffer as the expenditure patterns of agricultural universities and institutes differ greatly. In both countries there is a need to distinguish the roles of universities and research institutes and help them to prioritize applied, basic, and experimental research so that they may better address the needs of farmers. Private research could play an increased and important role in agricultural development, but this requires the development of a stronger funding structure and regulatory system to attract investors. In terms of capacity, while both systems have a large number of staff, there is a lack of specialized technical capacity in selected areas. Huang and Hu (2008) found that, when compared to other sectors, China's agricultural research system has a small number of highly trained scientists, highlighting the need to integrate agricultural research with the education system. Similarly, the Indian agricultural research system lacks capacity in emerging and specialized fields. As the SAUs are the main supplier of agricultural researchers, efforts should be made to further enhance the linkages between the research and extension systems.

4. Comparative analysis of extension systems and reform in China and India

China and India have been effective in orienting their public extension systems to be more problem-driven to some extent (Swanson and Rajalahti, 2010). In this section we discuss and compare the approaches and reforms the government took to increase the effectiveness of extension in China and India, respectively.

4.1 Analysis of extension system reforms in China

4.1.1 Reforms of the extension system in China. China has the largest agricultural extension system in the world. Table IX illustrates the distribution of the more than one million extension agents in China across the different areas of the agro-technical extension center system. Over the past 30 years, the Ministry of Agriculture has implemented a series of reforms to help the PAES become effective in meeting the needs of farmers. Agricultural extension reforms in China have come from three different approaches: commercialization, decentralization, and an inclusive extension

	SAUs					ICAR				
	No. of scientists			Entities		No. of scientists			Entities	
Category	Sanctioned	In position	(%)	No.	(%)	Sanctioned	In Position	(%)	No.	(%)
Agriculture	8,082	4,667	50	30	21	2,061	1480	32	41	23
Animal science	4,705	2,520	27	39	27	872	626	14	34	19
Horticulture	1,643	1,074	12	20	14	436	313	7	5	3
Fisheries	530	320	3	17	12	683	490	11	8	4
Engineering	979	554	6	21	15	1,019	732	16	34	19
Others	340	193	2	15	11	1,358	975	21	57	32
Total	16,279	9,328 (57)	100	142		6,429	4616 (72)		179	

Source: ICAR Annual Report and Agricultural Research Data Book (2014)

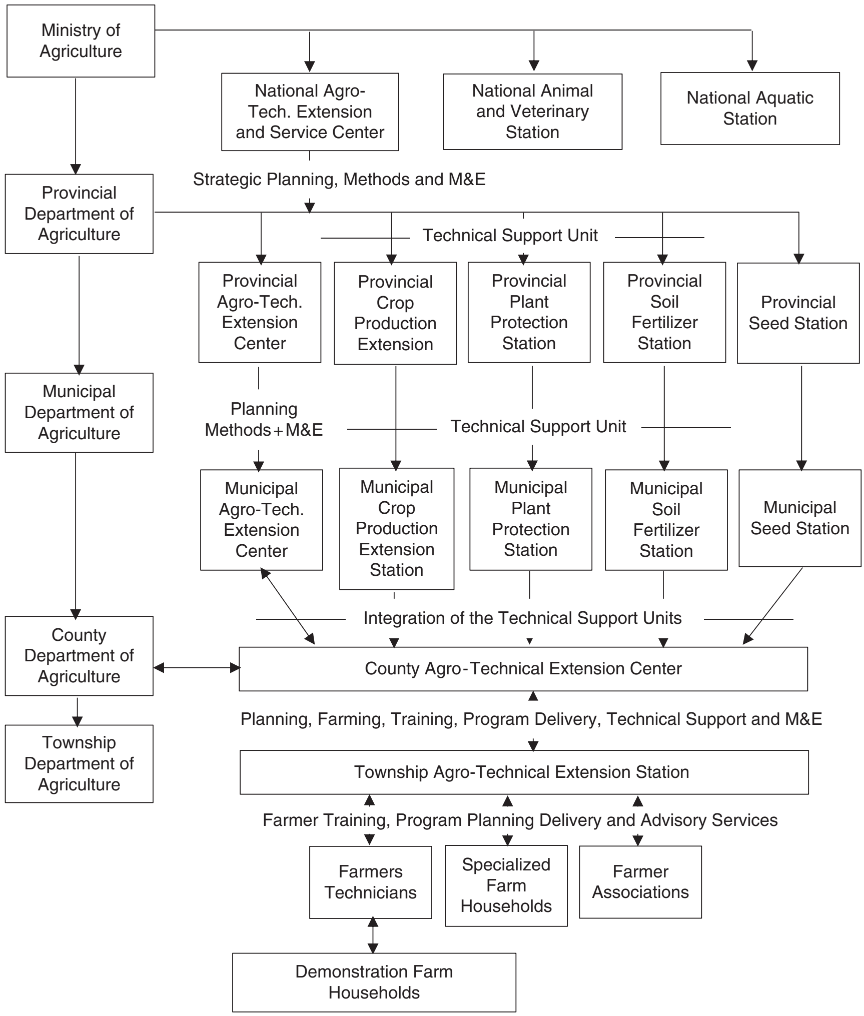
Table IX. Sector-wide public research scientists and entities in India 2010-2011 system pilot. The first round of extension system reforms in China aimed to commercialize PAES activities. Reforms were originally implemented to encourage individual PAES stations to earn money for their services and reduce the financial burden on the central government (Hu *et al.*, 2012a, b). As part of these reforms PAES stations were categorized as fully funded, partially funded, or self-funded, and counties were given the control over how to implement these reforms. As a result, extension agents were encouraged to become more entrepreneurial with the ability to generate income through commercial activities. However, a study of the commercialization of China's extension system found that this approach unintentionally encouraged extension agents to begin businesses selling agricultural inputs (Huang *et al.*, 2003).

In the late 1990s, decentralization reforms were put in place to shift administrative and financial responsibilities from county to township governments (Ferroni and Zhou, 2012b; Gao and Zhang, 2008). Under the Agriculture Support Services Program (ASSP), this reform shifted funding and focus to the CATEC and TATES, and reduce the county-level financial burden. Figure 5 below illustrates the decentralized system, in which all technical support units from crop extension were integrated at the county level (Swanson and Rajalahti, 2010). As a result, producer groups were able to utilize local extension stations to meet and conduct trainings, building the capacity of local farmers. Decentralization reforms also intended to reduce the financial burden on the central government. However, it was found that the decentralization of the extension system led extension agents to spend more time on administrative tasks rather than providing services to farmers (Hu *et al.*, 2009, 2012a, b).

4.1.2 Current status of extension. Table X shows the distribution of agricultural extension agents at the different levels and across areas of specialization. Since 1996, the number of extension agents has decreased, with a majority concentrated at the township level. To increase the impact of the Chinese PAES at the village level, the most recent round of reforms focussed on increasing the quality of services provided to farmers. The National Agricultural Technology Extension Service Center implemented a pilot of the inclusive public extension service reform, commonly referred to as the INC initiative. This reform was intended to encourage agents at the township level to take more of an initiative to meet the diverse agricultural information needs of beneficiary farmers (Hu *et al.*, 2012a, b). To ensure that the agents are more proactive, the reform includes a system of accountability and a monitoring and evaluation component. The evaluation system tracks the percentage of farmers visited in the responsible village, the number and type of services provided, and the responsiveness to emerging issues among other indicators (Hu *et al.*, 2012b).This system has three distinct characteristics: the inclusion of all farmers as target beneficiaries; effective identification of farmers extension service needs; accountability system to provide better extension, and technical advisory services to farmers (Huang and Rozelle, 2014). Following the successful implementation of the INC initiative, similar reforms have been implemented in many part of China. It was found that the inclusive reform initiative increased the availability and acceptance of public agricultural extension services across the board (Hu *et al.*, 2012a, b).

4.2 Analysis of extension system reform in India

While the need for an improved extension system in India is well recognized, the continuing reform process has yet to make the intended impact (Sulaiman, 2012; Babu *et al.*, 2013). Given emerging challenges such as a growing population, natural resource



Source: Swanson and Rajalahti (2010); Swanson *et al.* (2003)

Figure 5. Structure of agro-technical extension system in China

constraints, and climate change, producers need a wider range of support (Sulaiman, 2012). Growth in the agricultural sector is seen as a means of reducing poverty through increased incomes of smallholders, who comprise more than 80 percent of farming households (Sulaiman, 2012).

4.2.1 Reforms of the extension system. India's agricultural extension system has undergone major reforms in terms of its "governance structure, capacity, organization and management, and advisory methods" (Raabe, 2008). The public extension system played a key role in the dissemination of technologies central to the Green Revolution. This successfully led to the widespread adoption of high-yielding varieties (Babu *et al.*, 2013). In the late 1970s, the system focussed on the distribution of agro-inputs but operations became inefficient at both the central and state levels. Although the T&V

Table X. Distribution of extension agents in China, 1996-2006

		By administrative level			By specialization				
Year	Total	Above county[a]	County level	Township level	Crops	Livestock	Agricultural machinery	Aquatic products	Economics and management
Number of extension agents (1,000 persons)									
1996	1,025	69	375	581	421	332	139	24	109
1997	1,013	66	378	570	417	312	161	30	94
1998	1,058	60	358	640	407	338	183	34	95
1999	1,035	65	356	614	411	326	168	33	94
2000	1,013	71	353	589	415	320	153	32	92
2001	981	72	350	560	412	316	134	32	88
2002	934	68	343	523	401	299	119	30	84
2003	881	68	330	482	362	301	111	29	78
2004	832	66	320	446	345	292	95	29	72
2005	843	74	332	437	333	294	106	32	78
2006	788	73	318	397	326	266	97	28	70

Note: [a]Above country refers to prefectural, provincial, or national level extension units and agents
Source: Hu *et al.* (2009)

method was successful for a time, it was difficult to maintain the quality of staff and consistency of funding (Sulaiman, 2012; Babu *et al.*, 2013). The DOA was primarily responsible for extension activities, and focussed efforts on cereal crops. This narrow focus further problems in the system due to minimal collaboration with other line departments. Prior to reforms, separate extension activities were carried out by different line departments in each district. While successful during the Green Revolution, this management structure did not support the ability of smallholder farmers to intensify and diversify their agricultural production (Swanson and Rajalahti, 2010). This called for institutional reforms to increase the effectiveness of the agricultural extension system.

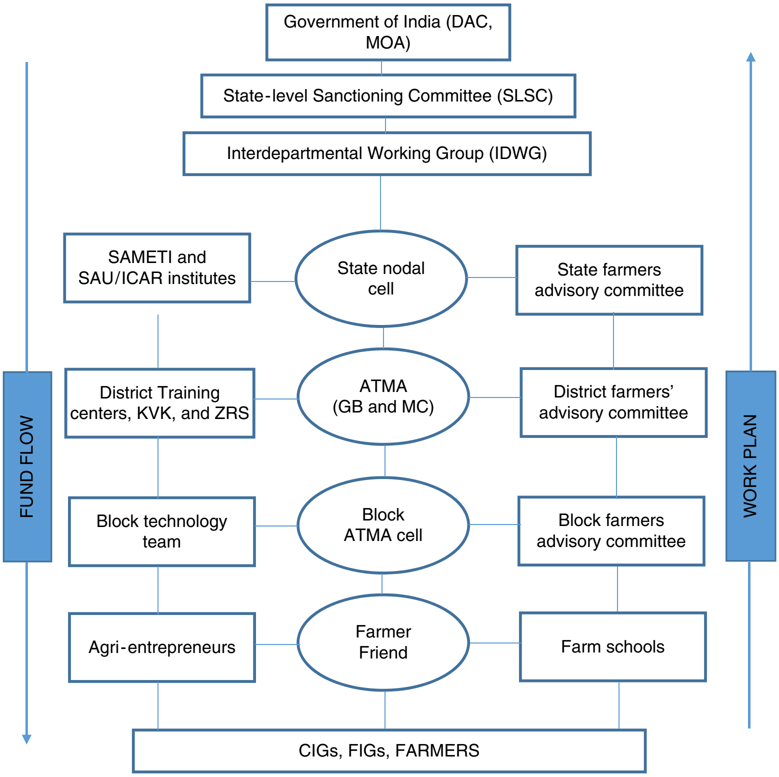
Two of the major research and extension reform initiatives were the World Bank-funded 1998-2004 Diversified Agricultural Support Project (DASP) and the 1999-2005 National Agricultural Technology Project (NATP). The DASP aimed to increase overall agricultural productivity, promote private sector investment, and improve critical physical and market rural infrastructure (Raabe, 2008). In addition, the initiative sought to increase farmers' incomes by supporting diversified farming systems. Complementing these efforts, the NATP sought to increase the effectiveness of extension institutions by improving the organization and management of the ICAR to increase its effectiveness (Glendenning *et al.*, 2010). The NATP initiative was also aimed at strengthening the capacities of researchers and research programs so that the system could effectively respond to the technological and information needs of farmers (Glendenning *et al.*, 2010; Raabe, 2008). Both initiatives included both supply and demand side components including enhancing agricultural productivity, capacity building, and changings in decision-making processes within the extension system (Glendenning and Babu, 2011). However, these programs were not sustainable without outside funding, therefore driving the need for domestic extension efforts.

The ATMA is a decentralized, semi-autonomous, and market-driven extension model which was originally piloted by the government in 1998 through funding from the World Bank. The key objectives of this approach included improving research – extension linkages and enhancing the coordination of activities between the numerous line departments engaged with farmers. This model was created in an effort to decentralize extension, particularly the mechanisms through which extension activities are funded, and to increase the demand-led nature of extension (Reddy and Swanson, 2006). In addition, the ATMA attempts to connect various non-governmental players including NGOs, CSOs, private sector, and farmers' organizations to meet the common objective of solving the technology challenges of farmers.

As opposed to the centrally funded system, the ATMA system allows individual ATMAs (which are registered as semi-autonomous NGOs) to directly receive national program funds (Swanson and Rajalahti, 2010). Funds can then be applied to address location-specific challenges to farmers. To further the contextualized nature of the ATMA, implementation of the ATMA is governed at the district level. Participatory planning processes address region-specific challenges to farmers and facilitate better coordination and the specific challenges of smallholders (Reddy and Swanson, 2006). The combination of collaborative partnerships, demand-driven decentralization of implementation, and service delivery mechanisms ensure accountability at the block, district, and state levels.

Although this program is seen as the key intervention for reforming the extension system in India, the ATMA still faces severe capacity and institutional constraints (Babu *et al.*, 2013). First, extension system is still structured as a "top-down" approach characterized by centralized decision making from the federal government. This structure allows little flexibility or creativity for the state governments to direct how programs should be implemented, preventing programs from being context-specific, and undermining the extension system. In 2010, the ATMA underwent major structural and management reforms to improve the impact of the program and address the main constraints including a lack of updated personnel at all levels; the absence of formal mechanisms to support extension delivery below the block level; inadequate infrastructure support to SAMETIs; and the lack of coordination with other extension schemes (Glendenning *et al.*, 2010). The revised structure of the ATMA is illustrated in Figure 6. The ATMA serves as a platform to integrate extension programming into various line departments, such as forestry, fisheries, and animal husbandry; encourage the flow of information public research and extension systems at the district level; and enable farmer input in decision making (Glendenning *et al.*, 2010; Swanson, 2006). However, the MOA did not approve the continuation of this model after the pilot, and resumed funding the ATMAs through earmarked funds. Reverting back to this top-down financing arrangement has inhibited the ability of the ATMA "bottom up" program to effectively plan programs, set priorities, and fund its strategy (Swanson and Rajalahti, 2010).

4.2.2 Current status of extension system. Currently, the ATMA operates in 639 districts in 28 states (Department of Agriculture and Cooperation (DAC), 2014). In 2013 alone, it is estimated that nearly four million farmers participated in ATMA activities such as exposure visits, trainings, and demonstrations, a quarter of which were female farmers (DAC, 2014). Due to the decentralized nature of the reform, funding for the ATMA is allocated on three levels: 77.53 percent for district programs, 10.25 percent for state programs, and 12.22 percent under the control of the Government of India (Agritech Portal). Additional extension programs in India include Agri-clinics and Agri-business Centers (ACABC) and the National Institute of Agricultural Extension



Note: DAC, Department of Agriculture and Cooperation; MoA, Ministry of Agriculture; GoI, Government of India; GB, Governing Board; MC, Management Committee; CIGs, Commodity Interest Groups; FIGs, Interest Groups; SAU, State Agricultural University; ICAR, Indian Council of Agricultural Research, SAMETI = State Agricultural Management and Extension Training Institute

Source: Glendenning *et al.* (2010) and Singh and Swanson (2006)

Figure 6.
Flow of extension information in India

Management (MANAGE). MANAGE aims to more effectively manage and modernize the extension system by providing professional training and capacity building for extension staff (Singh *et al.*, 2013).The government's expenditure on agricultural extension remains low. Table XI reports what the Ministry of Agriculture budgeted for agricultural extension between 2011 and 2014.

The reform initiatives undertaken in India indicate that improvements in agricultural productivity require "demand-driven, farmer-accountable, need-specific, purpose-specific, and target-specific extension services" (Raabe, 2008). In the context of Indian agricultural production systems, the agricultural extension reforms implemented aim at several strategic interventions. Improvements in the extension system are meant to enable farmers' provision of relevant information to meet their information needs. Ensuring such information reaches them in a timely manner lies at the center of Indian extension reform (Babu and Joshi, 2014; Babu *et al.*, 2013).

However, these reform measures have been only seen partial success. The orientation of the extension system in India is still largely centered on the production technology-related knowledge sharing. Yet there is great need for a holistic approach to an extension system that goes beyond the dissemination of production technologies.

4.2 Comparative analysis

Although the agricultural extension systems in China and India both aim to increase agricultural productivity and rural incomes, the system reforms implemented in each country are distinctly different. Both systems suffered from institutional constraints that limited their effectiveness to meet agricultural development targets. Constrains included top-down management and earmarked extension funding. Each country took a "best-fit" approach to address their organizational and management problems (Swanson and Rajalahti, 2010). Both countries implemented reforms to decentralize the agricultural extension system in order to provide more location-specific extension services. China decentralized the provision of extension services through the ASSP, increasing the authority of county-level offices. However, reform efforts to integrate crop and livestock extension were not implemented and the five extension divisions continue to operate separately. India reformed its agricultural extension in an attempt to create a more integrated, decentralized research, and extension system. Reforms in India occurred particularly at the district level by linking the KVKs with district level extension staff and programs (Swanson and Rajalahti, 2010). The creation of semi-autonomous ATMAs was intended to impact of extension efforts across a wide variety of farming households. While the reforms in India were focussed on integrating its research and extension efforts through KVKs, more could be done to enhance the extension system's ability to meet the needs of small farmers, particularly women. Despite a number of reforms and variety of approaches in agricultural extension in India, the reach of, access to, and quality of information provided to farmers remains uneven (Glendenning *et al.*, 2010). Additional efforts are needed in both countries to increase the involvement of the private sector and NGOs in the provision of extension in both countries.

5. Challenges in linking research and extension

The challenges of linking agricultural research with extension on the ground are common to many developing and transition economies. The original primary extension model in most countries was based on a linear concept of technology transfer. This was expected to function as an effective link between research, extension, and farmers (Swanson and Rajalahti, 2010). However, the evolution of extension has led to more market- and demand-driven systems, intended to be more responsive to the needs of

Year	Budget allocations Plan	 Non-plan	 Total
2011-2012	510.57	2.98	513.55
2012-2013	449.00	3.67	452.67
2012-2013 (revised)	409.60	3.90	413.50
2013-2014	462.00	4.05	466.05

Source: Ministry of Agriculture, Department of Agricultural Research, and Education Budget (2014)

Table XI. India ministry of agriculture expenditures on agricultural extension programs (in Rs crore) farmers. The structure of these systems means that the flow of agricultural information becomes more complex.

Both China and India continue to face organizational and management constraints to integrating research and extension. Table XII identifies challenges that the two countries face in linking AR&E. Although the scientific competence of research staff in China and India is very high, stronger linkages are needed to connect agricultural research institutions with the end users of their research (Stads and Rahija, 2012). Both China and India are challenged by the sheer size of their AR&E systems. The size and decentralization of each research system limits its ability to respond to the changing needs of farmers and consumers. In both countries, the duplication of research efforts and funding is a common problem. To remedy this, the research roles of public, private, and NGO actors should be more clearly established. With rapid economic growth and urbanization, both countries need to enable their research systems to respond to changes in consumer food demand. Agricultural extension in China continues to operate without an integrated approach. Services are planned and delivered to farmers in five separate divisions based on their production area (e.g. crops, livestock, etc.) In addition, extension and research efforts remain separate. Both countries lack an effective mechanism to monitor and evaluate the success of their research and extension programs.

6. Concluding remarks

In this paper, we collectively examined the research and extension systems in China and India to study the comparative status of reforms and possible options for further improvement. This comparative analysis provided some insight into the organizational, funding, and capacity constraints facing the AR&E systems in India and China.

Challenges	China	India
Setting research priorities	Top-down approach, focus on food security Partially driven by leading scientists rather than farmers' demand Unfocussed research priorities	Lack of a national strategy
Organizational and management challenges	Lack of incentive to link research to extension Duplication of efforts No integrated approach	Limited resources No sustainable funding Duplication of efforts
Knowledge/ information management	Limited coordination, often repetitions of research and extension efforts	Lack of transfer of knowledge from research to extension institutions due to limited individual capacity
Does research match the diverse needs of farmers?	Research system is not responsive Lack of NGOs to meet specialized value chain needs No monitoring and evaluation mechanisms	Need to increase extension linkages at the state level through SAUs (e.g. changes in curriculum) No monitoring and evaluation mechanisms
Role of private sector and NGO actors	Limited involvement of private sector or NGOs in extension	Increase the involvement of private sector and NGO to provide specialized services

Source: Authors' compilation

Table XII. Linking agricultural research and extension

The reform experience in China illustrates that technological change in agricultural production is the main engine for agricultural growth. China has attempted to reform its research system to become more modern, responsive, and efficient, however, the results of these efforts has been mixed. Reforming an agricultural research system to become more market-driven will lead to research efforts directed to address issues of food security, poverty alleviation, and environmental sustainability. As shown by the Chinese model, the commercialization of research requires a market-oriented institutional and management system. Reforms to commercialize the public research system should increase the ability of research institutes to generate income and attract private investment. However, not all research institutes and technologies can be commercialized. Therefore, it is important the research leaders assess current research demands.

Complementary lessons can also be derived from India's experience of reforming its agricultural research system. A lack of a consensus on a strategic vision for national public sector research has inhibited the effectiveness and impact of agricultural research efforts in India. In addition, ineffective national leadership to coordinate the numerous research institutions has led to many inefficiencies. The monitoring and evaluation systems for tracking both research programs and institutional changes need to be strengthened.

Agricultural policy makers in developing countries must acknowledge the need for reform to keep pace with global changes. This requires that the implementation of reforms be streamlined. In addition, research systems dominated by the public sector require an internal paradigm shift that links research funding with research outcomes and improving the relevance of research. This could be done through performance-based incentive and reward system for researchers and institutes. For large, decentralized research systems, effective management leadership within research institutions is critical to achieve the desired impact. This requires institutional innovations such as the ATMA model.

Recent reforms to promote inclusive public agricultural extension services in China have been successful in increasing access to these services for the rural population. It was found that farmers in reform villages adopted more public extension services than farmers in non-reform villages (Hu *et al.*, 2012b). These results illustrate that the traditional, top-down model can no longer meet the demand for diversified extension services. In addition, any extension reform requires substantial investments to improve the capacity of local extension agents to effectively transfer agricultural technology and information. Scaling up these reforms will also require substantial financial investment, especially when trying to create incentives to improve performance of agents.

As illustrated by India's extension reform experience, a shift from a top-down to bottom-up approach will require strong political commitment, particularly from local governments who will have more responsibility and accountability. If the management structure of extension systems is not properly organized, then the needs of larger, commercial male farmers will probably take priority. The extension paradigm in India must become more balanced to include both teaching and learning aspects in order to effectively address farmers' information needs and link farmers to both research and markets. In both countries, a system for monitoring the extension reform process needs to be created and implemented.

The comparative analysis of China and India presented here provides some lessons for system reforms in other developing countries. However, learning from similar comparisons of other developing countries can help speed up the process of reforms sorely needed for the transformation of agriculture.

Note

1. Third-party agency to manage research fund – www.most.gov.cn/ztzl/shzyczkjjhglgg/dtxw/zgrb/201410/t20141023_116303.htm

References

Anderson, J.R. and Feder, G. (2004), "Agricultural extension: good intentions and hard realities", *The World Bank Research Observer*, Vol. 19 No. 1, pp. 41-60.

Axinn, G.H. (1998), *Guide on Alternative Extension Approaches*, Food and Agriculture Organization of the United Nations, Rome.

Babu, S.C. and Joshi, P.K. (2014), "Reforming extension and advisory services in India: policy options and implications", in Singh, R.B. (Ed.), *Transforming Agricultural Education for Reshaping India's Future*, National Academy of Agricultural Sciences, New Delhi, pp. 387-408.

Babu, S.C., Joshi, P.K., Glendenning, C., Asenso-Okyere, K. and Sulaiman, V.R. (2013), "The state of agricultural extension reforms in India: strategic priorities and policy options", *Agricultural Economics Research Review*, Vol. 26 No. 2, pp. 159-172.

Beintema, N.M. and Stads, G. (2008), "Agricultural R&D Capacity and Investment in the Asia-Pacific Region," Research Brief No. 11, International Food Policy Research Institute, Washington, DC.

Benson, A. and Jafry, T. (2013), "The state of agricultural extension: an overview and new caveats for the future", *Journal of Agricultural Education and Extension*, Vol. 19 No. 2, pp. 381-393.

Birner, R. and Anderson, J.R. (2007), "How to make agricultural extension demand driven? The case of India's agricultural extension policy", *Intl Food Policy Res Inst*, Vol. 729.

Birner, R., Davis, K., Pender, J., Nkonya, E., Anandajayasekerem, P., Ekboir, J., Mbabu, A., Spielman, D., Horna, D., Benin, S. and Cohen, M. (2009), "From best practice to best fit: a framework for designing and analyzing pluralistic agricultural advisory services worldwide", *Journal of Agricultural Education and Extension*, Vol. 15 No. 4, pp. 341-355.

Bishwajit, G. (2014), "Promoting agricultural research and development to strengthening food security in South Asia", *International Journal of Agronomy*, Vol. 2014, Article ID 589809, pp. 6. doi:10.1155/2014/589809.

Chen, K.Z., Flaherty, K. and Zhang, Y. (2012), *China: Recent Developments in Agricultural Research, Agricultural Science and Technology Indicators: Country Note*, International Food Policy Research Institute, Washington, DC.

Department of Agriculture and Cooperation (DAC) (2014), "National mission on agricultural extension & technology", Annual report 2013-2014, New Delhi, available at: http://agricoop.nic.in/Annualreport2013-14/artp13-14ENG.pdf (accessed January 29, 2014).

Department of Science and Technology (DST) (2012), *Research and Development Statistics 2011-2012*, Department of Science and Technology, Ministry of Science and Technology, Government of India, New Delhi, available at: www.nstmis-dst.org/Rndststl1-12.aspx

Eicher, C.K. (2001), "Africa's Unfinished Business: building sustainable agricultural research systems", Staff Paper 2001-2010, Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Fan, S. and Gulati, A. (2007), *The Dragon and the Elephant: Agricultural and Rural Reforms in China and India*, Johns Hopkins University Press, Baltimore.

Fan, S. and Qian, K. (2005), "Institutional innovation and investments in Chinese agricultural research", in Fan, S. and Qian, K. (Eds), *Agricultural R&D and Poverty Reduction in China*, China Agricultural Publishing House, Beijing, (Chinese), pp. 1-14.

Fan, S., Omilola, B. and Lambert, L. (2009), "Public spending for agriculture in Africa: trends and composition," Working Paper No. 28, Regional Strategic Analysis and Knowledge Support System (ReSAKSS), Washington, DC.

Fan, S., Qian, K. and Zhang, X. (2006), "China: an unfinished reform agenda", in Pardey, P.G., Alston, J.M. and Piggott, R.R. (Eds), *Agricultural R&D in the Developing World: Too Little, Too Late?*, International Food Policy Research Institute, Washington, DC, pp. 29-64.

FAO (2012), *2000 World Census of Agriculture: Analysis and International Comparison of the Results (1996-2005)*, FAO Statistical Development Series 13, Food and Agriculture Organization of the United Nations, Rome.

Ferroni, M. and Zhou, Y. (2012a), "Achievements and challenges in agricultural extension in India", *Global Journal of Emerging Market Economies*, Vol. 4 No. 3, pp. 319-346.

Ferroni, M. and Zhou, Y. (2012b), "Review of agricultural extension in India", in Ferroni, M. (Ed.), *Transforming Indian Agriculture: India 2040*, Centennial Group International, Washington, DC, pp. 187-237.

Gao, Q. and Zhang, C. (2008), "Agricultural technology extension system in China: current situation and reform direction", *Management Science and Engineering*, Vol. 2 No. 4, pp. 47-58.

Glendenning, C. and Babu, S.C. (2011), "Decentralization of public-sector agricultural extension in India: the case of the district-level agricultural technology management agency (ATMA)", IFPRI Discussion Paper No. 01067, International Food Policy Research Institute (IFPRI), Washington, DC.

Glendenning, C., Babu, S.C. and Asenso-Okyere, K. (2010), "Review of agricultural extension in India: are farmers' information needs being met?", IFPRI Discussion Paper No. 01048, International Food Policy Research Institute, Washington, DC.

Hu, R., Liang, Q., Pray, C., Huang, J. and Jin, Y. (2011), "Privatization, public R&D policy, and private R&D investment in China's Agriculture", *Journal of Agricultural and Resource Economics*, Vol. 36 No. 2, pp. 416-432.

Hu, R., Cai, Y., Chen, K.Z. and Huang, J. (2012b), "Effects of inclusive public extension service: results from a policy reform experiment in Western China", *China Economic Review*, Vol. 23 No. 4, pp. 962-974.

Hu, R., Huang, J. and Chen, K. (2012a), "The public agricultural extension system in China: development and reform", background paper prepared for the Roundtable Consultation on Agricultural Extension, Beijing, March 15-17.

Hu, R., Liang, Q. and Huang, J. (2007), "Change in China's agricultural research investment and its international comparison", *Chinese Soft Science*, Vol. 184 No. 2, pp. 53-58.

Hu, R., Zhijian, Y., Kelly, P. and Huang, J. (2009), "Agricultural extension system reform and agent time allocation", *China Economic Review*, Vol. 20 No. 2, pp. 303-315.

Huang, J. and Hu, R. (2008), *The Development and Reform of the National Agricultural Research System: Policy Evaluations and Suggestions, Policy Newsletter*, Center for Chinese Agricultural Policy, Chinese Academy of Science, Beijing.

Huang, J. and Rozelle, S. (2010), "Agricultural development and nutrition: the policies behind China's success", *Asian Journal of Agriculture and Development*, Vol. 7 No. 1, pp. 93-126.

Huang, J. and Rozelle, S. (2014), "Agricultural R&D and extension", in Fan, S., Kanbur, R., Wei, S. and Zhang, X. (Eds), *The Oxford Companion to the Economics of China*, Oxford University Press, London, pp. 315-319.

Huang, J., Hu, R. and Rozelle, S. (2003), *Agricultural Research Investment in China: Challenges and Prospects*, China's Finance and Economy Press, Beijing.

Huang, J., Hu, R. and Rozelle, S. (2004), "China's agricultural research system and reforms: challenges and implications to the developing countries", *Asian Journal of Agricultural Development*, Vol. 1 No. 1, pp. 98-112.

Indian Council for Agricultural Research (ICAR) (2015), "Total number of employees in the ICAR", available at: www.icar.org.in/en/node/8022 (accessed March 31, 2015).

Jin, S., Rozelle, S., Alston, J. and Huang, J. (2005), "Economies of scale and scope and the economic efficiency of China's agricultural research system", *International Economic Review*, Vol. 46 No. 3, pp. 1033-1057.

Labarthe, P., Caggiano, M., Laurent, C., Faure, G. and Cerf, M. (2013), "Concepts and theories available to describe the functioning and dynamics of agricultural advisory services", available at: www.proakis.eu/sites/www.proakis.eu/files/Deliverable_WP2%201_concepts%20and%20theories%20of%20AKIS(1).pdf (accessed February 10, 2015).

Lin, J.Y. (1998), *How Did China Feed Itself in the Past? How Will China Feed Itself in the Future?", Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) Economics Program, Second Distinguished Economist Lecture*, CIMMYT, Mexico City.

Luo, W. (2014), "Third-party agency to manage research fund", *China Daily*, October 22, available at: www.chinadaily.com.cn/china/2014-10/22/content_18781828.htm (accessed February 15, 2015).

Ministry of Agriculture (MOA) (2013a), *National Statistics of Agricultural Science and Technology*, China Statistics Press, Beijing, (in Chinese).

Ministry of Human Resource Development (MHRD) (2010), *Statistics of Higher & Technical Education 2009-10.*, Bureau of Planning, Monitoring & Statistics, Ministry of Human Resource Development, Government of India, New Delhi, available at: http://mhrd.gov.in/statist?field_statistics_category_tid=32 (accessed February 2, 2015).

Ministry of Agriculture (MOA) (2013b), *Agricultural Science and Technology Statistical Materials*, Ministry of Agriculture, Beijing, (Chinese).

Ministry of Education (MOE) (2003-2013), *University Statistical Yearbook on Sciences and Technology*, High education Press, Beijing, (Chinese).

Ministry of Science and Technology (MOST) (2014), *China Statistical Yearbook on Sciences and Technology*, China Statistics Press, Beijing.

Mruthyunjaya and Ranjitha, P. (1998), "The Indian agricultural research system: structure, current policy issues, and future orientation", *World Development*, Vol. 26 No. 2, pp. 1089-1101.

National Bureau of Statistics of China (2014), *Chinese Statistical Yearbook 2014*, China Statistics Press, Beijing.

OECD (1991), *Development Assistance Committee: Principles for the Evaluation of Development Assistance*, Organization for Economic Co-operation and Development, Paris.

OECD (2010), *Challenges for Agricultural Research*, Organization for Economic Co-operation and Development, Paris.

OECD (2011), "Monitoring and evaluation for adaptation: lessons from development cooperation agencies", Working Papers No. 38, OECD Environment, Organization for Economic Co-operation and Development, Paris.

Pal, S. and Byerlee, D. (2006), "The funding and organization of agricultural research in India: evolution and emerging policy issues", in Pardey, P.G., Alston, J.M. and Piggott, R.R. (Eds), *Agricultural R&D in the Developing World: Too Little, Too Late?*, International Food Policy Research Institute, Washington, DC, pp. 155-194.

Qamar, K. (2005), *Modernizing National Agricultural Extension Systems: A Practical Guide for Policy-makers of Developing Countries*, Food and Agriculture Organization of the United Nations, Rome.

Raabe, K. (2008), "Reforming the agricultural extension system in India: what do we know about what works where and why?", Discussion Paper No. 00775, International Food Policy Research Institute (IFPRI), Washington, DC.

Reddy, M.N. and Swanson, B.E. (2006), "Strategy for scaling-Up the ATMA model in India", in Vreyens, J.R. (Ed.), *Proceedings from the 22nd Annual Meeting of the Association for International Agricultural and Extension Education*, pp. 561-569, available at: www.aiaee.org/attachments/article/849/561.pdf (accessed February 4, 2015).

Reeves, T., Pinstrup-Andersen, P. and Pandya-Lorch, R. (1999), "Food security and the role of agricultural research", in Coors, J.G. and Pandey, S. (Eds), *Genetics and Exploitation of Heterosis in Crops*, ASA-CSSA-SSSA, Madison, WI, pp. 1-8.

Rivera, W.M. and Sulaiman, V.R. (2009), "Extension: object of reform, engine for innovation", *Outlook on Agriculture*, Vol. 38 No. 3, pp. 267-273.

Rivera, W.M., Qamar, M.K. and Van Crowder, L. (2001), *Agriculture and Rural Extension Worldwide: Options for Institutional Reform in Developing Countries*, Food and Agriculture Organization of the United Nations, Rome.

Rosegrant, M., Ringler, C., Msangi, S., Zhu, T., Sulser, T., Valmonte-Santos, R. and Wood, S. (2007), "Agriculture and food security in Asia: the role of agricultural research in a changing environment", *Journal of SAT Agricultural Research*, Vol. 4 No. 1, pp. 1-35.

Singh, K.M. and Swanson, B.E. (2006), "Developing a market-driven extension system in India", in Vreyens, J.R. (Ed.), *Proceedings of the 22nd Annual Meeting of the Association for International Agricultural and Extension Education*, Clearwater Beach, FL, pp. 627-636, available at: www.aiaee.org/2006/index.html (accessed March 1, 2015).

Singh, K.M., Meena, M.S. and Swanson, B.E. (2013), "Extension in India by public sector institutions: an overview", Indian Council for Agricultural Research, available at: www.researchgate.net/publication/256092297_Extension_in_India_by_Public_Sector_Institutions_An_Overview/file/50463521b001c805a2.pdf (accessed February 2, 2015).

Stads, G. and Rahija, M. (2012), "Public agricultural R&D in South Asia: greater government commitment, yet underinvestment persists", ASTI synthesis report, International Food Policy Research Institute, Washington, DC.

Sulaiman, V.R. (2012), "Agricultural extension in India: current status and ways forward", background paper prepared for the roundtable consultation on agricultural extension, Beijing, March 15-17, available at: www.syngentafoundation.org/view/element_href.cfm?src=1/1081.pdf (accessed January 15, 2014).

Swanson, B.E. (2006), "Extension strategies for poverty alleviation", *Journal of Agricultural Education and Extension*, Vol. 12 No. 4, pp. 285-299.

Swanson, B.E. and Rajalahti, R. (2010), "Strengthening agricultural extension and advisory systems", Agriculture and Rural Development Discussion Paper No. 44, The World Bank, Washington, DC.

Swanson, B.E., Nie, C. and Feng, Y. (2003), "Trends and developments with the Chinese Agro-technical extension system", *Journal of the Agricultural and Extension Education Association*, Vol. 10 No. 2, pp. 17-24.

Umali, D.L. and Schwartz, L. (1994), *Public and Private Agricultural Extension: Beyond Traditional Frontiers*, World Bank Group, Washington, DC.

World Bank (2012), *Agricultural Innovation Systems: An Investment Sourcebook*, World Bank, Washington, DC.

World Development Indicators (2014), available at: http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators (accessed April 1, 2015).

You, L. and Johnson, M. (2008), "Exploring strategic priorities for regional agricultural R&D investments in East and Central Africa", IFPRI Discussion Paper No. 00776, IFPRI, Washington, DC.

Zhong, Z. (2014), "China agricultural extension: history, current status, and supply-demand characteristics", Asia-Pacific information platform for agricultural Policy, available at: http://ap.fftc.agnet.org/ap_db.php?id=194 (accessed March 30, 2014).

Zhou, Y. (2010), *Smallholder Agriculture, Sustainability and the Syngenta Foundation,* pp. 6, available at: www.syngentafoundation.org/__temp/Smallholder_Agriculture__Sustainability_and_the_Syngenta_Foundation.pdf (accessed January 10, 2015).

Further reading

Agritech Portal (2014), "Agricultural technology management agency", Tamil Nadu Agricultural University, Coimbatore, available at: http://agritech.tnau.ac.in/atma/atma_intro.html (accessed February 6, 2014).

Birner, R. and Anderson, J.R. (2008), "How to make agricultural extension demand-driven: the case of India's agricultural extension policy", IFPRI Discussion Paper No. 00729, International Food Policy Research Institute, Washington, DC.

Chen, K.Z. and Zhang, Y. (2011),), "Agriculture R&D as an Engine of Productivity Growth: China", prepared for the UK Government's Foresight Project on Global Food and Farming Futures. UK Government Office for Science, London.

Pal, S. (2008), "Agricultural R&D policy and institutional reforms: lessons from the experiences of India and China", *Economic and Political Weekly*, Vol. 28 Nos 26-27, pp. 145-155.

Venkatesh, P. (2013), "Recent trends in rural employment and wages in India: has the growth benefitted the agricultural laborers?", *Agricultural Economics Research Review*, Vol. 26, pp. 13-20.

Zhou, Y. (2011), *Smallholder Mapping II: Trends in Demographics and Driving Forces*, Syngenta Foundation for Sustainable Agriculture, Basel.

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