China's Agricultural Research System and Reforms: Challenges and Implications for Developing Countries

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The expansion of the real output of major food and agricultural productions in China ranks as one of the nation's great achievements. Publicly funded agricultural research has been key to the impressive performance (Huang et al. 2003). Expenditures grew rapidly from the early 1960s to the middle 1980s and the number of agricultural researchers increased throughout (Fan and Pardey 1992). The rising research investment resulted in a steady stream of productivity-increasing technology.

China was the first nation to extend semi-dwarf rice varieties, and drought- and pest-resistant wheat cultivars in the 1950s (Stone 1988). Its scientists also developed hybrid rice in the early 1970s and a number of successful varieties in the 1970s and 1980s. Several studies conducted by the Chinese Academy of Agricultural Sciences (CAAS) show that technology contributed more than 40% of agricultural growth (Zhu 1997). Recent studies on agricultural Total Factor Productivity (TFP) further confirm that agricul-tural productivity growth has mainly come from the technology changes, including the expansion of HYVs, other embodied input technology and improvement in farming system (Huang et al. 2000; Fan and Pardey 1997; Jin et al. 2002). The major output on agricultural research – improved varieties and farming system management – has come from national, provincial, and prefectural institutes as well as from agricultural universities (Huang et al. 2003).

There is concern, however, that the research system might have been weakened after the late 1980s. The overall funding for agriculture research stagnated during 1985-1995 (Huang and Hu 2000). Long lagged times between agricultural research expenditures and benefits mean that the adverse effects of shortfalls in expenditures will become evident only five or ten years later, which may partially explain the lower growth rates of crop, particularly grain yields in the late 1990s and the last three years.

On the other hand, the future demands on agricultural research in China will be sizable. The country has less than 10% of the world's arable land and one fourth of world per capita water availability, but already feeds more than 20% of the world's population. To keep pace with increased demands from projected population increases, food production in China will have to increase continually (Huang et al. 1999; World Bank 1997). Given the limitations on arable land, productivity increases will have to be the primary source of increases in output (Nyberg and Rozelle 1999).

To maintain higher food self-sufficiency levels, policymakers tried to raise funding for agri-cultural research by shifting the funding from institutional support to competitive grants, moving more funds from basic research to research aimed at solving the problems of economic development, and encouraging research institutes to be selfsufficient by selling their technology (Rozelle et al. 1997).

However, these policies have given rise to several questions. Can China's public agricultural research financing maintain a strong agricultural research system? How can China manage the commercialization of its part of the agricultural research? What is the role of the private sector in generating and providing agricultural technologies for the farmers? What kinds of reforms are necessary to improve the efficiency of agricultural research?

Answers to these questions are critical to policy-makers, producers and the agricultural industry in China. The lessons and experiences of China's agricultural research policies are also expected to have significant implications to many developing countries which are facing similar financing and institutional problems. The study attempts to shed some light on the questions listed above. The paper is organized as follows. In the next section, the existing structure of agricultural research system is reviewed. Section 3 examines the trends and structure of agricultural research financing and revenues. The current reforms and policies are discussed in Section 4. The final section provides the conclusions, policy recommen-dations for China's Government and implications to the other developing countries.

AGRICULTURAL RESEARCH INSTITUTIONS: AN OVERVIEW

Public Funding

Agricultural research in China is overwhelmingly financed and undertaken by the public sector; private-commercial agricultural research is minimal. The public research system comprised over 1,600 research institutes and more than 130,000 staff in 1999 (Table 1), plus about 55,000 retirees who are dependent on research institute budgets for their pensions. Public agricultural researches are conducted in the agricultural research institutes (Mainstream Agricultural Research System or MARS), universities, and non-agricultural research institutes. MARS personnel accounted for 83% in 1999, and the rest was about equally distributed between the universities and the research systems under other ministries. It is estimated that the number of research personnel from the private sector engaged in agricultural research is no more than 500 (Pray 1998). Research expenditure of the private sector is only about 1.7% of the nation's total agricultural research budget.

Decentralization

Ninety-five percent of the research centers and more than 85% of research staff are found in sub-national levels. Provincial and prefectural agricultural research institutes number 451 and 712, respectively (Table 1). Within MARS, the national level research institutes accounted for only 10% (or 8% of China's total staff) in 1999. Each province has its own provincial academy of agricultural sciences, at least one agricultural university, and several other agriculture-related colleges at provincial and prefecture levels. Most prefectures have their own agricultural research institute.

All core budgets of research institutes at provincial and prefectural levels are funded from the corresponding local governments. The research projects conducted at the provincial and prefecture institutes are financed mainly by local governments. In terms of budget allocation, national-level institutes within MARS account for only 12% of China's agricultural research budget (Table 2). Provincial and prefectural institutes account for 51% and 34%, respectively. In terms of the size of the staff among the institutes at various levels, the budget per staff at the national research institutes (77,000 yuan/staff) is higher than those at the provincial (54,000 yuan/staff) and prefectural levels (40,000 yuan/staff).

Staffing

Agricultural research in China is primarily built around the research institutes of the Chinese Academy of Agriculture Sciences (CAAS),[1] a series of provincial and prefectural academies, and

[1] There are five major agricultural academies at the national level. They are CAAS, the Chinese Academy of Fishery (Cafi), and South China's Academy of Tropic Plant (CATP) under the MOA, the Chinese Academy of Forestry (CAFo) under the State Forest Bureau, and the Chinese Academy of Agricultural Mechanization (CAAM) under both State Machinery Bureau and the MOA. However, CAAS is the largest in terms of staff and budget. In this paper, our discussions will mainly focus on CAAS, but policies and issues raised here are equally applied to the rest of the national agricultural research system.

Table 1. The number of institutes and staff of public agricultural research in China in 1999

	Total	University[a]	Others[b]	Sub-total	MARS National	Provincial	Prefecture
Number of institutes	1,635	312	104	1,219	56	451	712
Number of total staff	131,439	10,200	12,457	108,782	10,706	51,609	46,467
Staff per institute	80	33	120	89	191	114	65
Staff shares (%)	100	8	9	83	8	39	35
				(100) [c]	(10)	(47)	(43)

[a] Under universities, agricultural research staff are those professors or lecturers who have research projects in agriculture related fields while staff numbers in others column are the total staff, including all professional, support and other staffs working in and supported by the institutes.
[b] Includes those other than MARS and universities (i.e., Chinese Academy of Sciences).
[c] The numbers in parentheses are the staff shares (%) within MARS.
SOURCES: Authors' survey and database from Ministry of Sciences and Technology (MOST).

to a lesser extent, the agricultural university research system. Researchers in the universities account for only 8% of the total agricultural research staff and 7% of budget share (Table 2). Already over-staffing in agricultural research institutes and under-funded agricultural research system may partially explain the under-utilization of human resources in universities.

Research Orientation

Food security has been one of the central goals of China's national policy since the 1950s. The priority of research programs had been in basic staple food, particularly in grains in the 1960s-1970s. The rising income has resulted in changes in diet and increasing demand for non-staple food since the 1980s. Corresponding to these changes, the structure of agriculture has also been gradually moving to non-staple crops, livestock and other agricultural products.

However, even with these changes in the agricultural production structure, based on our surveys of over 1,200 agricultural research institutes under MARS, about 68% of the research budget was allocated to crops, 18% only for livestock and 14% for all others (Huang et al. 2003). These rates have been nearly constant over the last two decades. Because a large part of income of the poor is from crop production, the crop-oriented public research system ("pro-poor" system) contributes to both food security and poverty alleviation objectives.

Table 2. Total revenue of public agricultural research in China in 1999

	Total	University	Others[a]	Sub-total	MARS National	Provincial	Prefectural
Total revenue (million yuan)	6,846	478	889	5,479	827	2,772	1880
Revenue per institute ('000 yuan)	4,187	1,532	8,548	4,495	14,768	6,146	2640
Revenue per staff ('000 yuan)	52	47	71	50	77	54	40
Revenue shares (%)	100	7	13	80	12	40	27
			(100)[b]	(15)	(51)	(34)	

[a] Others include agricultural research institutes not under MARS and universities (i.e., Chinese Academy of Sciences).
[b] The numbers in parentheses are the revenue shares (%) within MARS.
SOURCES: Authors' survey and database from MOST.

CHALLENGES

Lack of Coordination

A decentralized research system has potential merits as it could easily prioritize research programs to meet local farmers' needs and develop appropriate technologies for local specific environments. However, there are also several disadvantages associated with this system. Less coordination among institutes can lead to duplication of research activities between regions, which may lower the overall efficiency of research investment for the country.

Also, given the financial constraints of many less developed areas in China, the decentralized system could have significant implications for agricultural technology changes and farmer's income growth in the poor areas. Inefficient resource allocation could be easily created from the management conflicts, and similarities of the research priority settings between the central and local governments, among various ministries (at the central government) or bureaus (at local government) at the same jurisdiction, and among local research institutes in similar regions.

Overstaffing

The inordinately large number of unqualified researchers, together with lack of research funding is the dilemma that China's agricultural research system is facing. Among the 130,000 personnel, about 70,000 are categorized as "active research" staff. In the absence of a national pension system, China's agricultural research also supports more than 55,000 retirees through the institutes' budgets. The active research staff is three times of that of the United States of America and the former Soviet Union (Table 3). This comparison does not intend to measure the research capacity, but to highlight the fundamental problems in China's research system, namely, overstaffing and a large number of unqualified researchers. Table 3 also shows that China's number of agricultural researchers per million US$ agricultural GDP is higher than all the other countries except East Germany. Such a

Table 3. International comparisons on number of agricultural scientists

	Number of active researchers				Number of agri. researchers per million US$ agri. GDP
	Public agri. research institutes	Universities	Private sector	Total number	
China (1999)	59,058	10,200	500	69,758	0.40 (0.69)*
India (1987)	4,052	5,800	600	10,452	0.16
Brazil (1995)	2,097	965	266	3,328	0.05
Argentina (1995)	1,051	61	110	1,222	0.07
Columbia (1995)	524	17	318	859	0.08
Mexico (1995)	1,365	464	901	2,370	0.14
Chile (1995)	189	50	13	252	0.05
USSR (1991)	23,144	0	0	23,144	0.46
East Germany					
(1989)	6,200	1,350	0	7,550	0.72
(1995)					(0.12)
West Germany					
(1989)	1,300	2,410	404	4,114	0.16
(1995)					(0.15)
Japan (1986)	11,154	3,605	8,850	23,609	0.13
USA (1991)	3,687	7,525	14,188	25,400	0.14

* Refers to total staff, instead of active research staff (0.40).
SOURCES: Pray and Umali 1998; Huang et al. 2003; and authors' survey.

resource distribution pattern is characteristic of the socialist economy regime.

In the socialist economy, the strategy in resource allocation is to replace the scarce capital by human resource with depressed wages. With the transition from planned to a more market oriented economy, the original wage level lagged far behind the expectations of the agricultural researchers. Consequently, agricultural researchers started shifting to work in other sectors as evidenced by the recent decline in the number of agricultural researchers.

Excess Burdens

The research institutes support a large proportion of retired staff. It is estimated that the ratio of working staff to retired staff has increased from 4:1 in the early 1980s to about 2:1 in 1999. For 1,219 agricultural research institutes under MARS, the retirees were 49 percent of the existing staff (Table 1). Because the core funding from the government has not been raised as much as the requirements for wage and pension system, an increasing portion of a research institute's budget is allocated to the payment for retired staff. For example, in CAAS, on the average 20% of the total academy's budget or 32% of the academy's core funding are spent on about 4,600 retirees (58% of working staff). In other research institutes such as the Institute of Crop Breeding and Cultivation and the Institute of Vegetable Crops and Flowers, payments for retirees account for almost the whole institutes' core funding.

AGRICULTURAL RESEARCH FINANCING

Agricultural research financing has been undergoing fundamental changes since the 1980s. Before the research reforms initiated in the mid-1980s, the government provided all of the funding for research. Planners allocated most funds through Five-year Plans with supplementary funding for special issues arising during the planning period. The former State Science and Technology Commission (SSTC) and now the Ministry of Sciences and Technology (MOST, after 1998) together with the Ministry of Agriculture (MOA) and other ministries wrote the research component of the plans with the assistance of special committees made up primarily of senior scientists from various disciplines. Most of the funds were then allocated on a formula basis to the research institutes mostly at the national levels.

A similar funding mechanism was followed at provincial and prefecture levels. The formula-based financing has been gradually shifted to competitive grants. Lack of funding to maintain the institute's operation has pushed agricultural research institutes to generate their revenue from commercial activities which has accounted for 41% of the total budget.[2] By the late 1990s, the government fiscal budget accounted for only about 50% of the total institute's budget (Table 4).

Sizes and Trends of Agricultural Research Investment

China's agricultural research system has remarkably expanded in the past five decades. The rapid growth of the agricultural research system has benefited from unrelenting efforts of the government. Expenditure for agricultural research in real terms grew by 13.5% annually between 1976 and 1985 (Huang et al. 1999). From the mid-1980s to the mid-1990s, however, government investment in agricultural research had not increased and even declined in many years (Table 4). This raised concern on China's ability to meet the growing demand for agricultural products resulting from the rapid growth of the economy. To make up for the slow growth and even decline in agricultural research expenditure after the mid-1980s, China re-started its growth in public investment in agricultural research after the mid-1990s.

1. Slow growth of total agricultural research investment. Total investment (including government fiscal expenditure and research institutes' commercial income) in agricultural research[3] grew from 1,355 million yuan in 1985 to 6,368 million yuan (current price) in 1999, representing an increase of more than four times (Table 4). However, measured at the real value (deflated by

[2] Surveys show that there is only about 5%-15% of commercial income invested in research projects. The rest of the commercial income is for salary and bonus of research institutes' employees, most of whom are working on commercial activities.

[3] Including agriculture, forestry, animal husbandry, water conservancy, and agricultural service.

Table 4. China's agricultural research investment in public research system in 1985-1999

Year	At current price (million yuan) Total	Fiscal	Commercial	At 1998 price (million yuan) Total	Fiscal	Commercial
1985	1,355	1,015	203	3,923	2,939	588
1986	1,346	958	200	3,676	2,617	546
1987	1,403	948	269	3,572	2,413	685
1988	1,782	1,189	366	3,827	2,554	786
1989	2,095	1,400	402	3,820	2,553	733
1990	2,050	1,243	499	3,661	2,220	891
1991	2,381	1,283	655	4,133	2,227	1,137
1992	2,761	1,442	840	4,548	2,375	1,384
1993	3,273	1,558	1,077	4,763	2,267	1,567
1994	4,409	2,072	1,322	5,272	2,478	1,581
1995	4,856	2,441	1,541	5,058	2,543	1,605
1996	5,238	2,754	1,580	5,143	2,704	1,551
1997	5,377	2,789	1,588	5,237	2,717	1,547
1998	5,847	3,060	1,687	5,847	3,060	1,687
1999	6,368	3,358	1,810	6,565	3,462	1,866
Annual growth rate (%)						
1985-95	13.3	8.4	21.8	3.6	-1.3	12.1
1996-99	6.5	7.4	3.9	6.5	7.4	3.9
1985-99	12.5	9.6	17.6	4.0	1.1	9.1

SOURCE: MOST.

general price index), the annual growth rate was only 3.6% over 1985-1995 or 4.0% over 1985-1999, below the growth rate of agricultural GDP (more than 4%) in the corresponding period.

2. Resumption of fiscal expenditure growth after the middle 1990s. Table 4 shows that the government fiscal expenditure for agricultural research in the real terms declined in 1985-1995. Annual growth rate was -1.3% (negative growth). It re-started growth at a rate of 7.4% annually in 1996-1999 (Table 4). Recent interviews with officials from the Ministry of Finance revealed that the annual growth rate of agricultural research expenditure has exceeded 10% in 2000-2003.

3. Rising commercial income with declining growth rate. Non-government fiscal investment or income generated by research institutes from commercial activities – a major increment of research institute's revenue in 1985-93 – decreased drastically after 1993 (Table 4). While annual growth rate reached 12.1% in 1985-95, it declined to 3.9% in 1996-99.

Intensity of Agricultural Research Investment

Internationally, investment intensity (that is, agricultural research investment expressed as a percentage of agricultural GDP) is usually used to measure the level of investment in agricultural research. Table 5 shows that the investment intensity of China's agricultural research declined during the period of 1985-1996 and resumed growth only recently.

Based on government budgetary allocations for agricultural research (excluding income generated by research institutes through the commercial activities), the percentage dropped from 0.40% in 1985 to 0.20-0.23% in the late 1990s. If the income generated by research institutes and the invest-ment in agricultural research by foreign companies and private enterprises are included, the intensity of investment in agricultural research was 0.44% in 1999. This is still one of the lowest investment intensities in the world (Table 6).

Investment in Agricultural Biotechnology Research

China considers agricultural biotechnology as one of the primary measures to improve its national

Table 5. Intensity (%) of investment in agricultural research and technical extension service in China, 1985-99

Year	Agricultural research			Agricultural technical extension
	Government fiscal expenditure	Commercial income and others	Total	
1985	0.40	0.13	0.53	na
1986	0.35	0.14	0.49	0.41
1987	0.30	0.14	0.44	0.40
1988	0.31	0.15	0.47	0.37
1989	0.33	0.16	0.50	0.36
1990	0.25	0.16	0.41	0.33
1991	0.24	0.21	0.45	0.34
1992	0.25	0.23	0.48	0.34
1993	0.23	0.25	0.48	0.32
1994	0.22	0.25	0.47	0.30
1995	0.20	0.20	0.40	0.27
1996	0.20	0.18	0.38	0.29
1997	0.20	0.18	0.38	0.31
1998	0.21	0.19	0.40	0.42
1999	0.23	0.21	0.44	0.46

SOURCES: Ministry of Finance and Agricultural Policy Research Center of the Chinese Academy of Agricultural Sciences.

food security, raise agricultural productivity, and create its competitive position in international agricultural markets. To achieve these goals, China immensely improved its innovation capacity of national biotechnology programs since the early 1980s. In contrast to the stagnation or even declining trends of public agricultural research staff and expenditure in 1985-95, the number of plant biotechnology researchers more than tripled in the past two decades.[4] It is estimated that there were about 2700 researchers (including support staff) working on plant biotechnology in 2003 (Table 7). If the animal sector is included, the number of agricultural biotechnology researchers may be more than 4000, which probably is one of the largest in the world.

The growth in agricultural biotechnology research investment in the public sector has been substantial. The estimated investment in plant biotechnology research was only US$4.2 million in 1986 when China formally started its "863 Plan" (Table 7). The investment grew to US$8.3 million in 1990, US$10.5 million in 1995, and US$38.9 million in 2000. The increase in 1995-2000 represented an annual growth rate of about 30%. The investment in the plant biotechnology research continued to grow in the first few years of the 21st century. The spending in plant biotechnology reached US$55.9 million in 2003, about 44% higher than that in 2000. Nearly all investment in biotechnology in China is from government sources (Huang et al. 2002).

Bt cotton is one of the most often cited examples of the progress of agricultural biotechnology in China. In addition, other transgenic plants with resistance to insects, disease or herbicides, or plants with improved quality have been approved for field release and some of them

[4] This is based on a survey of 29 research institutes in the plant biotechnology in 2000, interviews with the ministries and research institutes in 2002, and the most recent research institute survey in 2004.

Table 6. Intensity of agricultural research investment in the middle 1990s

Region	Investment intensity (%)			Share (%)	
	Gov't	Non-gov't	Total	Gov't	Non-gov't
Mainland China (1999)	0.23	0.01+0.21[a] =0.22	0.45	51.1	48.9
Taiwan	4.65	na	na	na	na
Other Asian countries					
India	0.37	0.06	0.43	86.0	14.0
Malaysia	0.58	0.15	0.73	79.5	20.5
Thailand	0.69	0.10	0.79	87.3	12.7
Indonesia	0.24	0.02	0.25	96.8	7.2
Pakistan	0.47	0.02	0.49	95.9	4.1
Latin America					
Argentina	0.82	0.05	0.88	94.3	5.7
Brazil	0.83	0.12	0.95	87.4	12.6
Chile	0.64	0.05	0.69	92.8	7.2
Columbia	0.26	0.15	0.41	63.4	33.6
Mexico	0.36	0.28	0.64	56.3	43.7
Peru	0.76	0.14	0.91	83.5	16.5
Venezuela	0.82	0.08	0.90	91.1	8.9
Developed countries					
Japan	2.10	2.22	4.32	48.6	51.4
Australia	3.54	1.54	5.08	69.7	30.3
UK	2.29	3.80	6.09	37.8	62.2
France	2.24	2.52	4.76	47.1	52.9
Germany	1.88	2.66	4.54	41.4	58.6
US	2.02	2.34	4.36	46.3	53.7
16 high-income countries[b]	2.37	1.86	4.23	56.0	44.0

[a] The figures are for private (0.01) and income generated from development activities (0.21) by research institutes.
[b] The figures for 16 high-income countries are the figures of late 1980s.
SOURCES: Rozelle, Huang, and Pray, forthcoming; Pray and Umali 1998.

Table 7. Estimated research staff and annual expenditure on plant biotechnology research in China, 1986-2003

Year	Staff	Research expenditure		
		Million RMB at current price	Million RMB at 2000 price	Million US $
1986	740	14	38	4.2
1990	1,067	40	68	8.3
1995	1,447	88	87	10.5
2000	2,128	322	322	38.9
2003	2,690	462	463	55.9

Note: Expenditures include both project grants and costs related to equipments and building.
SOURCE: Huang et al. 2004.

are nearly ready for commercialization. Among others, these include:

1. transgenic cotton lines resistant to fungal disease;
2. rice resistant to rice stem borer or bacteria blight, diseases and herbicide;
3. wheat resistant to barley yellow dwarf virus;
4. maize resistant to insects and with improved quality;
5. poplar tree resistant to Gypsy moth;
6. soybeans resistant to herbicides; and
7. transgenic potato resistant to bacterial disease or Colorado beetle (Huang et al. 2004).

From 1997-2003, the National Agricultural Biosafety Committee received a total of 1,044 (821) cases of GMOs (GM plants) for field trials, environmental release, pre-production, and commercialization, of which 777 (585) cases were approved. Eighteen transgenic cotton varieties generated by Chinese institutions and five varieties from Monsanto with resistance to bollworm had been approved for commercial-ization in China in 1997-2002. While several GM varieties of tomato, sweet pepper, chili pepper, and petunia have also been approved for commercialization since 1997, the areas under these four crops are very small.

Challenges Ahead

While there has been increasing investment in agricultural research since the middle 1990s, China's agricultural research is still much under-invested. Insufficient research budget could severely affect the stability of the agricultural research system and the enthusiasm of researchers. Based on interviews, the time spent on research activities by agricultural researchers dropped from 74% in 1985 to about 50% in the late 1990s.

Improvement of agricultural research capacity is the other challenge that China has to hurdle. For the country as a whole, the PhD degree holders average only 0.57 for every 100 agricultural research staff in 1999 (Table 8). The percentage of researchers who hold PhD degrees differs largely among research institutes. It was 2.84% in national research institutes and 0.58% in provincial research institutes. Although prefectural research institutes employed more than 46,000 staff, only 12 researchers held PhD degree (or 0.03% of total staff) in 1999. A similar pattern holds true for researchers with MS degree (Table 8).

The need to beef up research capacity is as urgent for the less developed regions under China's highly decentralized research system. While the decentralized system has its own merits, it may also present some constraints for agricultural productivity growth, food security and poverty alleviation in poor areas as local ability to invest in agricultural research depends on local income and financial capacity. Table 9 presents agricultural research investment intensities (ARII) by region,

Table 8. Agricultural research staff by education and position for national and local research institutes under MARS in 1999

	Total staff	PhD	MS	BS	Professor + associate professor	Senior research assistant
Total	108,782	615	2,871	22,323	11,816	19,747
National	10,706	304	754	2,805	1,763	2,244
Provincial	51,609	299	1,836	11,374	6,572	9,426
Prefecture	46,467	12	281	8,144	3,481	8,077
		As percentage of total staff (%)				
Total		0.57	2.6	21	11	18
National		2.84	7.0	26	16	21
Provincial		0.58	3.6	22	13	18
Prefecture		0.03	0.6	18	7	17

SOURCE: MOST.

Table 9. Regional agricultural research investment intensity (%) under MARS in 1999

Region	Excluding national institutes in the region	Including national institues in the region
Total or average	0.32	0.37
Southwest	0.20	0.21
North	0.26	0.35
East	0.29	0.33
Central	0.34	0.35
Northwest	0.39	0.51
South	0.41	0.46
Northeast	0.49	0.56
Western	0.26	0.30
Central	0.30	0.33
Eastern	0.36	0.43

Note: Eastern China includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan; Central China includes Shanxi, Inner Mongonia, Jilin, Heilongjiang, Anhui, Jiangxi, Hunan, Hubei, and Henan; Western China includes Sichuan, Chongqing, Yunnan, Guizhou, Tibet, Shaanxi, Gansu, Ningxia, Qinghai, and Xingjiang.

which shows negative correlation between ARII and economic development or income. Western China had the lowest value of ARII (0.26%), followed by Central (0.30%) and Eastern (0.36%) China. The difference of ARIIs between Western and Eastern China is even larger when the investment in national institutes located in the regions is included.

Western China is the least developed region with average per capita income of 1,502 yuan in 1999 (Table 10). Nearly half of China's rural poor is located in the region. Western China's poverty incidence (7.3%) was nearly 6 times as high as that in Eastern China (1.3%).

NATIONAL STRATEGY TO REFORM AGRICULTURAL RESEARCH SYSTEM

The reforms in the agricultural research sector vividly illustrate the propensity of the leadership to implement deep reforms in even the most tradition-bound sectors (Maddox and Swinbanks 1995; Rozelle et al. 1997). As part of China's general move to distance itself from the rigid, closed planning system, reformers gradually implemented a series of science and technology policies that were designed to fundamentally alter the behavior and output of research institutes. In addition to opening to the outside world, the agricultural research reforms of the 1980s and 1990s targeted two main areas. The first was changes in the basis of the distribution of research funds to a more competitive system, focusing resources on the most productive scholars and institutes. The second was policies encouraging research institutes to commercialize the products of their research, allowing them to retain profits and reinvest as a major source of revenue for their research work. Since the late 1990s, a new reform aimed at modernizing the agricultural research system has been initiated.

Reforms before 1999

1. Competitive grants and focused research programs. Beginning in the early 1980s, national research policy gradually increased the proportion of funding allocated competitively by encouraging funding agencies to make grants and fellowships

Table 10. Regional income and poverty in rural China, 1999

	Average per capita income (yuan)	Population under poverty (million)	Percentage of porverty in nation's total (%)	Poverty incidence (%)
Western	1,502	16.44	48	7.3
Central	2,003	12.67	37	3.9
Eastern	2,929	5.01	15	1.3
China	2,210	34.12	100	3.7

SOURCES: MOA 2000 and NSBC 2000.

to researchers putting forth the best proposals. Prior to that time, directors of research institutes and their department heads allocated the fund provided by SSTC to projects, laboratories, and individual scientists.

Currently, most research funds from national sources can only be accessed through competition. National leaders also competitively allocate funds for priority research areas, such as biotechnology research, through programs like the 863 program and Special Foundation for Transgenic Plants. Most of the national and provincial STCs (Science and Tech-nology Committees) have expert committees made up primarily of scientists who rate proposals on the basis of the expected contribution to farmers, the proposed methodology, originality, etc.

While the gradual trend towards competitive grants dominated the funding of agricultural research project in the 1990s, all institutes still get "administrative fees" (or *shiyefei* or core funding) on a formula (noncompetitive) basis from MOA or their local budgetary authorities for base salary, pension and other operation costs. For the most part, administrative fees are used for the research staff's basic salaries and benefits, such as housing subsidies and medical assistance.

One of the biggest uses of administrative fees has been to support an institute's retired personnel. Frequently, when administrative funding from a unit is insufficient to support its welfare needs, an institute's director will invariably divert research grants by raising overhead rates or allowing project members to have the right to withdraw a portion of grants (normally ranged from 5% to 15%) as a "bonus" for their project staff to meet the fiscal needs.

Shifting the criteria for dispensing research grant from the old formula to a more competitive basis is expected to significantly impact on research productivity and the government's priority areas for research. The research productivity may increase with the reform as larger funding can be allocated to more productive research institutes and individual scientists. Meeting the government's targets in such areas as food security, poverty alleviation and environmental protection can also be easily incorporated into research programs chosen competitively.

2. Commercialization reforms. Policymakers began encouraging research institutes to earn their own income through commercial activities in the mid-1980s. In 1987, the SSTC chairman announced a plan to push scientists to think like entrepreneurs. MOA officials soon copied the SSTC moves, encouraging agricultural research institutes to earn money (Liu 1991). Researchers interviewed recall that they initially gave little credence to the new directive since seed prices were heavily subsidized and there was little prospect of making a commercially viable product except for seed.

As budgets became increasingly tight and the need to reform grew, the nature of commercialization evolved. Reformers originally had designed the policy changes as a way to encourage institutes to capitalize on breakthroughs in research. It soon became an accepted practice, however, to make money in any way possible. Income generated from commercial activities raised rapidly in the late 1980s and early 1990s (Table 4).

In the early reform period, commercial activities ranged from selling products produced by own institutes (e.g., plant breeding institutes sell new plant varieties) to activities that are far from the unit's traditional discipline such as running hotels and restaurants or selling industrial products. Recently, more income has been generated from the technologies closely associated with the agency's area of expertise.

Unfortunately, a weak intellectual property right (IPR) system makes licensing of a technological breakthrough, a non-viable option for manufacturing enterprises or technology development firms. Licenses and technology contracts typically are not honored for very long. For an economy with hundreds of millions of small farmers, the cost of enforcement or strict implementation of a strong IPR system, if it is not impossible, could be extremely high. More frequently, a research establishment can partially capitalize on a breakthrough by manufacturing and distributing the product itself.

3. The impact of the reforms. Rozelle et al. (1997) found that China's agriculture reforms were only partially successful. Although the real income from commercial enterprises increased rapidly from 1985 to 1994, only a small amount of that income was used to fund research. The funds generated from commercial activities were insufficient to offset the shortage of government support for research. Moreover, the growth of income generated from the commercial activities slowed down after the early 1990s.

On the other hand, while competitive grant funds may have focused resources on the better scientists, funding for agricultural research projects in real terms did not increase for all types of research institutes. Since a number of staff members in commercial enterprises did not move off the rolls, funds per scientist did not go up, as officials had hoped.

While there has been an increase in technology transfer because of the commercialization process, the change has not been significant. In fact, much of the commercialization in the early reform period by public agricultural research institutes had little relationship to the technology they are responsible for developing. Intellectual property rights and contractual law in China apparently are too weak for technology to be profitably and successfully licensed.

Because of these reasons, the common perception by the late 1990s was that the reforms, though perhaps successful in the beginning to change the structure of China's research institutes, had only partially reached the goals or targets that the reformers expected.

A New Push for Reform

1. Strategy and plan. The perceived failure of earlier reforms to provide new technologies to producers, and to cure the twin problems of duplication of research among institutes and overstaffing, has created a new impetus to launch another round of research reforms. In addition, the needs arising from China's move to a more market-oriented economy and the challenges of research in the new high technology fields occasioned further reforms in the agricultural research system. In this new round, the challenge that officials have set for themselves is a daunting task, namely, to create a modern, responsive, internationally competitive, and fiscally sustainable agricultural research system (State Council 2000). The goals to better commercialize its products and raise funding per scientist are necessary to attract and retain the best people engaged in agricultural research.

To meet the above goals, the government laid down several measures to modernize the agricultural research system. The reforms have attempted to separate the current research activities into those that can be commercialized (most are pure applied research) and those that should be maintained in the public "research innovation base" (most are applied-basic and basic researches, and those with strong public goods nature). For those left in the non-commercial sector, the outstanding research staff and researchers with potential are separated from those without potential. Those identified as high quality scientists have received higher salary and have a large increase in per capita support.

Based on the above principles, MOST officials drew up a 1/3-1/3-1/3 plan for agricultural research reform in the late 1990s. Reformers believe that by fully commercializing some agricultural research institutes or specific research programs or activities in each research institute, one third of the institute's staff could be separated from the research system. During the transition phase of reforms for those institutes or programs/activities to be commercialized, the core funding would be gradually reduced, until the revenues of the institute-cum-enterprises become fully dependent on outside sales.

On the other hand, those institutes and programs in the institutes that partly provide public goods (named as non-profit public institutes which are also believed to account for about one third of total staff), receive public funding to cover part their expenses. The rest of the agricultural research system is maintained and placed into an innovation base and given a raise in both core funding (particular the researchers' salary) and research budgets.

The ultimate objective of China's research reform is to have a modern, state-of-the-art, internationally competitive agricultural research system. With such high competition, they hoped to be able to attract better scientists. Higher levels of funding for the better researchers were expected to keep the latter from diverting their attention from research into other activities such as consulting or commercial activities. MOST predicted that in such a system (that would also give the research institute's director more discretion over salaries and hiring), more scholars from overseas would also be attracted to return.

2. Challenges of recent reforms. A recent study shows that institutes face several challenges during the reforms – even with considerable additional investment (Huang et al. 2003). First, support for the retired staff has been a serious problem. For example, on average in CAAS, pension and medical payments to retirees took up 32% of the core funding in 1999. The average ratio of retired staff to currently active staff was 0.6:1 in 1999, ranging from 0:1 (in newer or growing research institutes such as the Biotechnology Research Institutes) to nearly 1:1 (in older research institutes such as cropping- oriented research institutes). In the traditional institutes which have been around for many years and have an aging staff and many retirees, more than half of the core funding is allocated to pensions and health care. Active scientists in these research institutes rely mostly on project funding or consulting for their salaries.

National research directors also pointed out that without a firm commitment to increase funding, the national research system might not follow the path directed by MOST. Some institutes in the rich regions that initiated the commercialization reform in the late 1990s have gradually returned to the government for support. In the less developed provinces where local government financial revenue generation is weak and investment in agricultural research is not viable, leaders used research reform as a mechanism to cut the budget. Quickly, however, reformers in the less developed provinces and even in the more developed coastal provinces found that few agricultural research institutes could succeed commercially. Those that struggled include institutes that were originally thought to be engaged in "applied" research. The main question is whether or not these institutes can survive in China's current institutional and legal system after they were commercialized under their current management.

Management problems were bound to arise as academics do not always make good businessmen and the managers seldom are given real authority to restructure the firm. According to interviews, managers were almost always prohibited from laying-off workers. In the minds of institute managers, commercialized enterprises must continue to take care of their retirees and other employees, otherwise they will become the burden of the institute.

Another problem that hampered commercialization efforts is the unfavorable business environment for many firms in the agriculture sector. A poor intellectual property rights system and fragmented technology markets (e.g., for seed) and other factors keep agricultural technologies from prospering. Low profit rates, high transaction costs for servicing small producers, and other high costs of doing business limit the commercialization of many firms.

3. Lessons and new policies. In facing the problems confronting agricultural research, China's leaders have realized that while reforms are needed, increasing financial support is a necessary condition for success. Even with successful commercialization, large increases in budgets are needed to fund the elite scientists at levels needed to modernize the research sector and to attract the best minds in the country. Recently, commodities and technologies which have strong public goods feature and social implications have been strengthened within the public research system. Meanwhile, other commodities and technologies with high possibility of private sector entry have been commercialized gradually with support from the public sector.

Although commercialization of many of the institutes can succeed and contribute to budgetary savings, policymakers have also recognized that the process might take time. A longer time period with more support is needed to allow for a redirection of effort and restructuring of the firm. Recently, managers have been given authority in some institutes to lay off workers and provide a better incentive system for the enterprises to operate profitably.

CONCLUDING REMARKS AND IMPLICATIONS TO OTHER DEVELOPING COUNTRIES

China is highly acclaimed for its ability to feed its growing population despite the extremely limited natural resources. Over the last four decades, per capita availability of food, household food security, and nutrition all have improved significantly. Increased domestic production is almost solely responsible for increased per capita food availability and significantly contributes to poverty alleviation and farmers' income.

China's experience shows that technological change in the developing countries is the main engine for agricultural growth, increased farm income, and poverty alleviation. Publicly funded agricultural research has played critical roles in generating the technologies for the needs of hundreds of millions of farmers. However, the success of research-led technology changes in the past does not imply that agricultural research will be necessary to effectively meet the farmers' demand for agricultural technology in the future. Many things are undergoing changes.

This paper shows how China has been trying to reform its overburdened, public-dominated and decentralized research system in order to establish a modern, responsive, efficient, and internationally-competitive agricultural research system. The study shows that commercializing agricultural researches does not imply a weakening of the government's role in financing agricultural research. Agricultural research driven by commercial interests would naturally be directed towards the most commercially viable products and technologies. Market-driven research system will lead research directed toward food security, poverty alleviation, and environmental sustainability. The crucial role of agricultural research necessitates that government be a primary source of funding in the decade to come. The efforts and cost needed to enforce a strong IPR system also imply the importance of a viable public financial support system for agricultural research.

There are a few other lessons and experiences that resulted from China's agricultural research investment and reforms, which may also have implications to the other developing countries. These include the following:

1. The commercial component of the research reforms may not be successful if other reforms (such as output, input and technology market reforms) have not taken place in the rest of the economy.
2. Not all agricultural research institutes and technologies can be commercialized.
3. The commercial businesses of the research institutes require a market-oriented institutional and manage-ment system.
4. Academics need to learn marketing and management skills to successfully operate commertical enterprises.
5. The importance of public and local research on biotechnology is recognized.

The fact that Bt cotton was developed by government researchers in parallel with its development by international companies clearly made it more palatable to the government and ensured that there was a strong lobby in favor of the technology.

China's leaders recently raised agricultural research investment substantially and took a decisive step to reform and strengthen its public agricultural research system. These have many implications for the developing countries that are facing similar financial and efficiency problems in the public research system. Although funding through various possible sources from non-government financial channels is expected to increase in the future, a thorough reform of the existing public agricultural research system should be accompanied by the implementation of other policies and reforms particularly those related to lifting the barriers for private participations in research and technology transfer.

To increase the ability of commercialized research institutes to generate income and to attract private investment in agricultural research, the reforms should continue to focus on: i) liberalizing agricultural input and output markets; ii) implementing and enforcing the policies related to IPR and ownership; iii) reducing the barriers to market access for private participants in the research and technology sector; and iv) providing greater government funding for research to assist local firms in the initial stages of private development.

The research capacity and technology gaps between rich and poor regions and their implications for income distribution have not been adequately addressed in the current research system in China. As the bulk of funding local research institutes comes from the corresponding local government's fiscal revenue, it is expected that the technology gap between the rich and poor regions would increase if the lack of coordination between national and interregional institutes continues to plague the current decentralized system, and if regional research investment would be neglected by policymakers in the future.

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