China

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The demand for agricultural products is growing rapidly in China due to per capita income growth and population growth. The primary way to increase production is to increase yield per unit of land through improved technology. This technology has to come from Chinese public and private research or from imports of technology by the public or private sector. In other research, we have shown that research outputs and inputs of public research institutes are stagnant or declining in China (Pray, Rozelle, and Huang, 1997). In developed countries, increasing private research has made up for declines in public research. In China, however, no one has examined whether any private research is taking place and, if there is any, what private research is doing. One of the main purposes of this chapter is to describe how much research is being conducted by private firms in China and the potential for further growth of private research. A second purpose is to assess the role of private firms in transferring food and agricultural technology to China.

We found that very little agricultural research and technology transfer is financed or conducted by private firms in China, which is not surprising considering the short period of time that private firms have been able to operate in China and the relatively small contribution of the private sector to China's GDP. Private research expenditure in China was estimated at $11-$16 million in 1995 (table H-5), which is a small amount relative to the $480 million of public research expenditures. It is also small relative to private research elsewhere in Asia. Private firms invest $50 million in India, $19 million in Thailand, and $17 million in Malaysia (see the applicable country case studies). Foreign technologies have had a limited impact on Chinese agriculture in recent years, chiefly in the areas of poultry genetics and pesticides. In addition, technology embodied in foreign direct investment appears to have had some impact on the food industry. Plant varieties, biotech products, and agricultural machinery from abroad have had little or no impact in recent years.

Given these findings, a third objective of this chapter is to ascertain why private research is so limited and what could be done to increase the contribution of the private sector. The conclusion is that the agricultural input sector is still dominated by state-owned enterprises and other government organizations which limits the role of private firms in marketing, importing, production, or research in the agricultural input industry. A second factor, which limits research by those private firms that are able to operate in China, is the weakness of intellectual property rights. A third factor is that rapidly changing industrial policy and regulatory structures add considerable risk to any investment—particularly a long-term investment like research.

The good news is that the potential for growth of agricultural research and technology transfer is great once the policy constraints are removed. The potential market is huge, and many biological inventions developed in the developed countries need relatively little adaptive research for the temperate climate of China. Allowing 20 percent of the pesticide market to foreign firms led to $5-$10 million annual investment in R&D in just 10 years. Nine seed firms are doing about $1.7 million of plant variety research per year despite the fact that their ability to sell seed profitably is greatly restricted. Allowing them a large share of the market, reducing regulations, and strengthening intellectual property rights could lead to a major expansion of private research.

The chapter starts with a general description of the agricultural sector and agricultural input industries in China. It then describes the types and quantities of the agricultural research and technology transfer activities of private food and agricultural input firms, documents the impact of these research and technology transfer activities on agriculture, examines the reasons for the low levels of private research and technology transfer, and discusses policy options for increasing private activity.

Agriculture in Transition to a Market Economy

Agriculture

Agricultural production has been growing rapidly since the reforms of the agricultural economy that started in 1978. Total value of production in the agricultural sector grew at an annual rate of 7.5 percent from 1978-84 and 5.6 percent from 1984-95 (table H-1). Within the agricultural sector, livestock grew particularly rapidly at about 9 percent for both periods. Livestock was led by poultry meat production, which increased five-fold between 1985 and 1994, egg production, which increased 3.5 times, and swine production, which doubled; fisheries production grew almost 14 percent per year. Among crops, fruit production grew very rapidly, while the major grain crops and cotton grew at much slower rates or declined.

Growth in demand due to per capita income growth has been the driving force behind these increases. It is projected that per capita income will at least double the demand for red meat, poultry, and fisheries products by the year 2020 but may reduce the consumption of food grains (table H-2). This means that the demand for animal feed and feed grains will also increase very rapidly.

Technology has allowed Chinese farmers to supply agricultural products to meet most of this demand. Huang and Rozelle (1996) have shown that improved

Table H-1—Growth rate of China's agricultural economy by sector and selected agricultural commodities, 1970-96

	1970-78	1978-84	1984-95	1996
		Percent		
Agricultural output:				
Total value	2.3	7.5	5.6	9.4
Crop	2.0	7.1	3.8	7.8
Forestry	6.2	8.8	3.9	5.6
Livestock	3.3	9.0	9.1	11.1
Fishery	5.0	7.9	13.7	13.92
Grain production	2.8	4.7	1.7	8.1
Rice	2.5	4.5	0.6	5.3
Wheat	7.0	7.9	1.9	8.2
Maize	7.0	3.7	4.7	13.8
Soybean	-1.9	5.1	2.9	0.1
Cash crops:				
Oil crops	2.1	14.9	4.4	-1.8
Cotton	-0.4	7.2	-0.3	-11.9
Rapeseed	4.3	7.3	5.4	-5.9
Peanut	-0.2	10.8	5.2	-0.9
Fruits	6.6	7.2	12.7	10.4
Red meats	4.4	9.1	8.8	11.9
Pork	4.2	9.2	7.9	10.7

	1978	1980	1985	1990	1994	1995	1996
				Billion 1985 yuan			
Value of real agricultural output	226	285	362	608	966	1,129	1,235
Crop	170	208	251	404	659	788	851
Forestry	8	13	19	32	44	49	52
Livestock	43	59	80	141	223	249	277
Fishery	4	6	13	22	39	43	49

Note: Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms.
Sources: Growth rates-from Huang Jikun FAO Report 1998.
Value of output—SSB, Statistical Yearbook of China, various issues; MOA, Agricultural Yearbook of China, various issues.

Table H-2—Projected annual per capita food consumption under baseline scenario in China, 1996-2020

Alternative scenario	1996	2000	2005	2010	2020
	Per capita food grain consumption (kg)				
Food grain	191	192	192	190	180
Pork	17	20	23	26	32
Beef	2	2	3	3	4
Mutton	1.2	1.5	1.8	2.2	2.9
Poultry	4	6	7	8	11
Aquatic	7	10	12	14	19

Source: Projections by Dr. Huang Jikun. Chinese Center for Agricultural Policy. 1998.

crop varieties, along with complementary inputs such as fertilizer and irrigation, were the major forces in the growth in crop production since 1978. The source of most of this technology has been Chinese national, provincial, and prefectural government research. Chinese scientists developed Green Revolution type rice varieties about the same time that the International Rice Research Institute developed them, and they developed the world's first commercial hybrid rice varieties, which are now grown on about half the rice area in China.

In addition, Chinese scientists and officials brought in technology from abroad and adapted it to Chinese conditions. In the 1940s and 1950s, Chinese scientists brought in cotton, corn, and sorghum varieties from the United States and elsewhere. These imported varieties and hybrids were gradually modified to be resistant to China's pests, diseases, and cultural practices (Stone, 1988). Chinese pesticides were copies of chemicals originally developed by private firms in the United States, Europe, and Japan but produced using methods of production developed in China. Agricultural machinery is based on Japanese, Western, and Soviet designs and modified to meet local needs.

Improved breeds, feed, and management techniques have made major contributions to the increase in swine and poultry production. Imported breeds have made a major contribution to swine production. In the early 1990s, 30-50 percent of all hogs slaughtered were crossbreeds (Simpson, Cheng, and Miyazaki, 1994). The foreign breeds were developed by private firms and imported by government institutions, which crossbred them with local breeds. Foreign poultry breeds started coming in during the 1980s. Private firms sold parent or grandparents to government and joint venture hatcheries or commercial producers. Private firms now account for almost all of the broilers and some 70 percent of the layers.

The major policy goals of the government have been to keep prices of basic foods low and to ensure that the country is self-sufficient in basic food and fiber production. The political importance of these often contradictory goals has led the government to continue to intervene in agricultural markets more than in other sectors of the economy. After a period of liberalization of agricultural produce and input markets in the early 1990s, the government seems to be intervening more in recent years.

Agricultural Input Industries

China is one of the largest agricultural input markets in the world. It is the first or second largest producer of seeds, pesticides, fertilizers, and tractors in the world. In value terms, it is not as highly ranked because of the low cost of many of the inputs. Growth in production has varied considerably between the different input industries (table H-3). Production of large and medium-size tractors has declined since the mid-1980s, while production of mini-tractors and implements for mini-tractors has doubled since the mid-1980s. Fertilizer use has doubled. Pesticide production increased by 2.5 times. Commercial feed production has increased by at least 7 times from 9 million Yuan in 1985 to 67 billion Yuan in 1995 (1995 Yuan; interview with Chai Tai, July 1998).

State-owned enterprises (SOEs) have a major share in the importation, production, distribution, and marketing of all modern inputs. Their share of production is almost 100 percent of commercial (not farmer-saved) seeds, agricultural machines, and nitrogen fertilizers. Joint ventures play a small but growing role in pesticide production, swine genetics, and imports of P and K fertilizer. Poultry genetics is the only area in which joint ventures are the main producers or importers of technology.

Table H-3—Characteristics of agricultural input industries

Industry	Quantity of production 1984	Quantity of production 1995	Value of production	Percent State-owned enterprise production	Percent of farmer purchases from government
Seed	2,500,000	3,500,000 mt (12,500,000 mt total)	$5 billion	100% of hybrids 5% of varieties	100% of hybrids 5% of varieties
Pesticides	135,000 mt (1986)	349,000 mts	$1.0-1.7 billion	80	100
Fertilizer	1,739,800 tn	3,317,900 tn (1994)		> 50	50
Agricultural machinery	853,914 large tractors 3,294,000 mini-tractors	693,154 large tractors 8,237,000 mini-tractors (1994)	$7.5 billion	100	50
Feed	Feedstuff imports 248,846 mt $50,168,000	Feedstuff imports 991,743mt $316,202,000 (1996) 3,458,124mt $993,087,000 (1997)	$8.4 billion	Limited	Limited

Source: Seed: H. Reddinger and Zhang Jianping 1997. *Planting Seed. Annual Report*. American Embassy, Beijing, China.
Pesticide quantity and value: Industry estimates.
Fertilizer and agricultural machinery quantity: China SSB, China Statistical Yearbook, 1995. *China Statistical Publishing House.*1995
Agricultural machinery value: Industry estimates
Feed imports: FAO AgroStats; Value: Industry estimates

Government institutions also control the distribution and marketing of most agricultural inputs. Almost all of the 4 million tons of commercial seeds are supplied by government enterprises. By law, government-owned seed companies must supply hybrid seeds of the major field crops. Seeds of non-hybrid field crops are primarily produced and saved by farmers with 10 to 20 percent of the total coming from SOEs (Reddinger and Zhang, 1998). Vegetable seeds are produced by farmers, SOEs, TVEs, and private firms. About half the fertilizer comes through government agencies. Pesticides can be purchased from many traders as well as the plant protection service, and agricultural machinery can be purchased from a number of different shops in towns.

State-owned input industries depended upon research institutes in the industry that they were affiliated with for process and product technology. In the pesticide industry, for example, there are 12 major state-owned synthesis research centers that develop active ingredients and better ways to produce existing active ingredients. In 1992, the Ministry of Chemical Industry (MCI) decided to form two major agrochemical research centers—Shanghai Pesticide Research Institute, funded and directed by the SOE Shanghai Zhongxi, and a northern research center based at MCI's Shenyang Chemical Research Institute with a satellite branch at Nankai U's Element Institute. The announced goal of the government at that time was to eventually spend Y1 billion per year on pesticide research to develop new chemicals that could compete in foreign markets with the international companies. The budgets for these research institutes now is about Y200 million.

The Ministry of Machine Building has four research institutes that are supposed to develop improved agricultural machinery and improved production processes.

Government policymakers in the agricultural sector believe that agricultural input industries still need assistance in competing with foreign competition. Local “infant industries” need time to consolidate, increase their efficiency, invest in research and start competing nationally and globally with foreign firms. This concern may have been heightened by the recent rash of mergers and acquisitions in biotechnology, seeds, and agricultural chemicals in the United States and Europe. Scientists and policymakers have expressed concern about being dependent on a few foreign companies for seed and other essential agricultural inputs of the grain and cotton sector. Iraq is brought up as an example of what could happen.

One result of these concerns is policies that restrict imports of agricultural inputs and joint ventures. Imports of agricultural inputs (table H-4), such as seeds and agricultural chemicals, have been limited by quotas, bans, and other types of barriers. For example, parent stock of poultry cannot be imported, no nitrogen fertilizer can be imported, and only 20 percent of the pesticide market is allotted to imports. In addition, imports of most inputs must be done by government agencies or government-designated firms. Regulations, such as phytosanitary requirements, compulsory testing of plant varieties, and biosafety regulations, can also be used as non-tariff barriers to imported technology.

Another result of these concerns and a general desire for more efficient industry is the recent government policies of consolidating SOEs into fewer, larger, and more efficient units. The government is cutting them off from subsidies and government loans unless the loans can be commercially justified. Many SOEs and new government-owned commercial units are investing in or at least forming alliances with research institutes. They are setting up joint ventures with government research institutes, funding contract research by government institutes, or starting their own in-house research by hiring scientists from government research institutes. In the agricultural machinery industry, for example, the agricultural machinery companies are being encouraged to consolidate into four or five groups, one of which concentrates on engines, another on large tractors, a third on combine harvesters, etc. Research is being incorporated into the leading firms in these groups. The Luoyang Tractor Research Institute joined the China No. 1 Machinery Engineering Company, and the Shanghai Diesel Engine Research Institute joined the Shanghai Diesel Engine and Tractor Industry Company. Likewise in the pesticide industry, the number of SOEs has been reduced drastically, and the Shanghai Pesticide Research Institute has become a part of Shanghai Zhongxi, a major firm with pesticide sales of about $80 million, of which $20 million come from exports.

Agricultural input industries have far less foreign direct investment than industry as a whole in China (table H-4) in part because of policy restrictions. As

Table H-4—Foreign direct investment and imports by industry

Industry	FDI value (billion yuan to end of 1995)	Foreign enterprise share of industry assets (Percent)	Value of imports, 1996
Food - Processing[1]	54.85	20.50	$2,900 mil (1994 SSB)
Manufacturing	39.51	32.19	
Ag. sector (farming)	21.33[2]	very small	$1,600 mil (1994 SSB)
Seed	NA	Very small	$42 mil. (exports $38 mil.)
Pesticides	1.55	7.49	$137 mil (1994) (exports $276 mil)
Agricultural machinery	1.72	3.46	
Fertilizer	1.58	1.38	$1,938 mil (1994)
Ag. sector (animal husbandry)	16.00[2]	very small	$816 mil (1994)
Feed industry	12.34	34.10	$316 million
Vaccines and veterinary medicine	0.19		
All industry (not just ag inputs and food)	2,500.00	19.09	

[1] Includes feed industry.
[2] Calculated based on Chen Chunlai (1998). Table H-7 shows about $8 billion FDI in agriculture of which 33% is in farming and 25% in livestock from his table 8 (the rest is forestry, fisheries, and agricultural services). Used exchange rate of 8 yuan per $1.

Sources: FDI and Foreign Enterprise share: "Foreign Direct Investment in China's Agriculture and Agriculturally Related Industries." Unpublished paper. University of Adelaide. 1998.
Value of food processing, ag.sector, pesticides, and fertilizer import: China SSB, *China Statistical Yearbook*, 1995. China Statistical Publishing House.1995.
Value of seed imports: H. Reddinger and Zhang Jianping 1997. *Planting Seed.* Annual Report. American Embassy, Beijing, China.
Value of feed imports: FAO Agrostats.

mentioned above, foreign firms are restricted to 20 percent of the pesticide industry and excluded from hybrid seed production. Foreign companies can operate only as joint ventures. In seeds and agricultural chemicals, the regulations on joint ventures are more restrictive. A 1997 seed industry regulation requires joint ventures dealing with grain, cotton, and oilseed to be majority Chinese owned, to make a minimum investment of $2,000,000, and to do all research under the joint venture. A 1996 regulation on the agricultural chemical industry required joint ventures to sell only products whose active ingredient and major intermediates are manufactured in China. A recent attempt by a large foreign agricultural machinery company to establish a joint venture was turned down by the Planning Commission because the foreign firm would have had the majority ownership.

Commercial Agricultural Research and Technology Transfer

A preliminary survey of firms, discussions with government scientists and officials, and a review of patent data in 1997 led to the conclusion that there was very little research by China's private agricultural input firms (Pray, 1997). Therefore this study concentrated on private research by foreign firms and joint ventures between foreign and Chinese firms. Since there are no government records or other studies of the amount and impact of private research, it was necessary to conduct a survey of private firms. Personal interviews or telephone interviews were conducted by the author in the United States with 14 U.S.- or Europe-based multinationals during the winter and spring of 1998.[1] Then in China in the summer of 1998, the author, with the assistance of Dr Chen Chunlai from the U. of Adelaide and Dr. Huang Jikun, the head of the Chinese Center for Agricultural Policy, conducted interviews with two Chinese firms 16 foreign or joint venture firms, and a number of public sector scientists and policymakers.[2]

[1]Cargill, Mycogen, Pioneer, KWS, DeKalb, Delta and Pineland, American Cyanamid, Monsanto, Busch Agricultural Foundation, Quaker Oats, PIC, Hubbard, Arbor Acres, and Avian Farms.

[2]Seeds: Cargill, Chai Tai Seeds, Delta and Pineland/Monsanto, Denghai Seed Co.
Pesticides: Agrevo, American Cyanamid, Bayar, FMC, DuPont, Monsanto, Shanghai Zhongxi
Poultry: Arbor Acres, Beijing Poultry Breeding Co. Ltd.
Ag. machinery: John Deere, New Holland, Kubota
Others: Simplot, Chai Tai Feed Mills.

Agricultural technology transfer into China is probably conducted by a much larger number of firms than those that have formal research programs. Therefore, the interviews were supplemented with data on the numbers of food- and agriculture-related patents and on foreign direct investment in food and agriculture.

Private Research

Private research has grown rapidly from zero in 1985 to $11-$16 million today (table H-5). This is impressive growth in a 10-year period. However, as mentioned above, this is still a small amount relative to public investments or private firms in other Asia developing countries. Table H-6 shows the amount of private research investment in six other Asian countries. China ranked fourth in the total amount of money invested in private research behind India, Malaysia, and Thailand. China ranked last in private research intensity (research/ agricultural GDP) and in private research as a share of total agricultural research.

The agricultural chemical industry spends more money on agricultural research than any other input industry (table H-5). All of the private firms conducting agricultural chemical research in China are joint ventures with foreign firms. Their agricultural chemical research consists primarily of testing pesticides that have already been commercialized elsewhere. These tests are for the efficacy of the active ingredient and formulations against pests and diseases. Some research is on combining different active ingredients into effective new products. There are also tests of the environmental impact of active ingredients and formulations. Some companies have set up their own experimental fields, but most hire local scientists to conduct the experiments for them. The results of the tests are used to register new chemicals. A few foreign firms test some of their early generation compounds here because it is inexpensive to do so. Four firms reported contracting government research institutes to synthesize new chemicals and to conduct some very preliminary early screening of these materials for biological activity. The new chemicals are then shipped to the United States or Europe for further screening.

The seed industry is primarily testing varieties that were bred outside China, although three or four companies are doing some breeding for local conditions. Research on major field crops is concentrated on corn and a few other crops. Of the nine seed firms about which we have information (eight joint ventures and one local firm), seven are working on corn.

Table H-5—Research and development by industry, 1995

Industry	Research objectives	Amount of research	Impact of new technology
Seed	Testing foreign hybrids, a few firms have breeding programs Corn, sunflower, sorghum, rapeseed, cotton, vegetables.	$1,700,000 (9 joint ventures + 1 local)	Small amount of impact in sunflower, cotton, corn, watermelon. Possibly larger impacts on sugarbeets.
Pesticides	Testing chemicals for efficacy and environmental impact. Current emphasis on herbicides but working on fungicides and insecticides also. Contract synthesis and early screening by a few firms.	$5 to 10,000,000 (9 joint ventures)	
Agricultural machinery	Testing new small-scale rice harvesters, improving quality production process of small tractors and harvester	Small amount (3 joint ventures)	
Fertilizer	More efficient application of phosphorus and potassium		
Poultry	Breeding for more dark meat	$3,000,000 (1 joint venture)	Broilers with higher percent dark meat
Feed	Reduce cost of feed production		Reduces cost of commercial feed.
Food industry	Improve quality of potatoes, barley, oats, for use in french fries, beer, and oatmeal	$1,000,000 (4 joint ventures)	Identified high-quality varieties.

Source: Survey by author, 1998.

Table H-6—Private and public research and research intensity in Asia, 1995

	Private R&D	Public R&D	Private R&D intensity	Public R&D intensity
	Million 1995 US$[1]		*R&D as % ag GDP*	
Large, low-income countries				
China	16.0 (3)	479.5	0.008	0.327
India	55.5 (14)	347.9	0.059	0.370
Middle-income countries				
Malaysia	16.6 (21)	64.0	0.150	0.577
Thailand	17.4 (12)	127.0	0.095	0.691
Mid-size, low-income countries				
Indonesia	6.1 (12)	44.4	0.018	0.132
Pakistan	5.7 (19)	25.0	0.036	0.159
Philippines	10.5 (22)	37.5	0.064	0.230
Total	127.8 (11)	1,125.3		

[1]Calculated using official exchange rates.
Parentheses show private research as a percent of total agricultural research expenditure.

Sources: Pray and Fuglie, 1999.

Sunflower, sorghum, rice, and rapeseed are each the subject of research by two companies, while one company works on sugarbeets and another on cotton and wheat. These companies hire Chinese and a few foreign scientists to conduct the research. The land is leased or owned by their joint venture partners. Some testing of varieties is contracted out to government experiment farms or by the seed testing stations. The main goal of the grain and oilseed research is to identify foreign or local hybrids or varieties that can increase farmers' yields. Pest and disease resistance is also an important research goal. Grain quality or fiber characteristics in cotton are an important but secondary breeding goal in some crops. These companies also conduct some agronomic research to develop the best cultural practices to go with the new varieties. One important Chinese practice, which they are working to change, is the extremely high seed rates, a residual from farmers' experience of cheap, poor quality seed from government institutions.

The only agricultural biotechnology research by a private firm that we were able to identify was by Monsanto in collaboration with the cottonseed company Delta and Pineland (which Monsanto is in the process of purchasing in the United States). They have been working on identifying the best varieties of genetically engineered cotton for Chinese conditions and developing the crop management practices that will give farmers the maximum economic benefits from these varieties. Some other seed firms may be experimenting with transgenic varieties in greenhouses but only Monsanto has applied to test transgenics in the field.

A few food processing firms are conducting agricultural research on barley, oats, and potato varieties. Food processing firms are interested in identifying local or foreign varieties that meet their quality standards and cost the same as or less than imports. High yield per unit of land is an important research goal in order to reduce cost of production.

The private vegetable seed industry does little research. No private firm reported any plant breeding. Almost all research by vegetable seed firms is the testing of foreign varieties. In contrast, public research organizations are conducting a lot of vegetable breeding research. Three public vegetable research institutes—CAAS in Beijing, the provincial academy in Hunan, and the prefectural institute in Tianjin—have set up successful commercial seed businesses to sell varieties that they bred.

A few foreign companies are doing very applied engineering research to improve local agricultural machines. John Deere is working on improving harvesters and combines to differentiate their products from the Chinese products. The wheat combines are small (55 hp) by international standards but are large in China. The small harvesters for rice, which Japanese firms have recently commercialized, are the subject of research by Yanmar and Kubota. Firms are also looking for ways to reduce the cost of machinery production.

One joint venture company is doing poultry breeding in China. That company, Beijing Poultry Breeding Company (a joint venture between the Beijing City government, the Thai firm Chai Tai, and Avian Farms in the United States) has a major broiler breeding program. It is trying to produce a bird with more dark meat and less white meat than the standard international breeds. Other firms import breeds from abroad after testing under local conditions.

In the mid-1980s, a joint venture between a foreign swine genetics company and the Animal Husbandry Bureau in Wuhan established a farm that was to breed improved swine. However, the partnership did not work out and the farm has now been downgraded to multiplying and supplying foreign breeds.

There is a scattering of privately funded research in other agriculturally related industries. The feed industry does some work on identifying the nutritional characteristics of new possible feed inputs. Pharmaceutical industries do trials on new veterinary pharmaceuticals and vaccines.

Private Technology Transfer

The chemical industry also appears to be the most important source of imported technology. Table H-7 shows the number of food and agricultural invention patents. The number of patents is one of the few quantitative measures of technology transfer in China. About 13,000 patents have been issued in China to the food industry and agriculture and agricultural input industries, but there has been more foreign patenting in agriculture (3,074) than in food (1,862). Agricultural chemicals account for two-thirds of foreign patents in agriculture followed by animal husbandry with about 400. Only a few foreign patents were taken out on agricultural machines, plants, or fertilizer. The data in table H-7 also show that, in general, food and agriculture had a lower percentage of foreign patents than was the case with all patents, about half of which were issued to foreigners. Twenty-three percent of agricultural patents and 15 percent of food industry patents were issued to foreigners. The pesticide industry is the one component of food and agriculture related industries in which foreign patents exceed the number of domestic patents.

Foreign investment is the primary means of transferring technology internationally. Technology is embodied in the technology that is purchased using the foreign capital. Thus, another indicator of technology

Table H-7—Chinese agricultural and food invention patents, 1985-97

Patent categories (international patent classification)	Total number of patents	Patents issued to foreigners[1]	Foreign/total
	--------------Number	*--------------*	*Ratio*
Food industry	12,675	1,862	0.147
Ag. inputs			
Fertilizer	966	97	0.100
Pesticides	3,741	2,091	0.559
Plants	370	91	0.246
Machines	2,711	97	0.036
Animal husbandry	2,412	414	0.172
All agriculture (Most ag. inputs + forestry, fisheries, livestock)	13,281	3,074	0.231
All categories	148,336	73,465	0.495

[1]Citizens or corporations from the United States, Canada, Japan, Taiwan, Hong Kong, Australia, France, Germany, the Netherlands, Switzerland, and the United Kingdom.

Source: Data from Chinese Patent Office.

transfer is foreign direct investment (FDI) statistics (table H-4). The FDI data suggest that despite the relatively low number of patents, food manufacturing has received a considerable amount of foreign technology. The low number of patents may be due to the fact that technology can be better protected through secrecy or technical means rather than patents. Crop farming and animal husbandry received large amounts of FDI but, as a percentage of total assets in farming or the size of the agricultural sector, the amount of FDI was rather small. The agricultural input industries, with the exception of the feed industry, have had very little foreign investment. This fits with the patent data and information gathered in our interviews with firms. Among agricultural chemicals, most of the patented technology is imported pesticides. Only a few foreign companies have set up production facilities in China.

Current and Potential Impact

The main achievement of private research has been to identify foreign technology that would work well in China. Thus, in this section we mainly concentrate on the current and future impact of imported technology.

Recent Technology Transfer by Foreign Companies

In recent years, imported agricultural technology has been important in poultry and swine. Grandparent stock of most commercial broilers (chicken for meat) is imported or was developed based on U.S. poultry breeds. The joint venture Beijing Poultry Breeding Co. supplies 40 to 45 percent of the grandparent stock of broilers while Arbor Acres controls a third of the market. The layer industry is less concentrated, but it primarily uses foreign breeds also (CABS, 1998). Swine used in large commercial operations are primarily crosses with foreign breeds. In the early 1990s, 30-50 percent of all hogs slaughtered were crossbreeds (Simpson, Cheng, and Miyazaki, 1994). Most of the exotic breeds were imported from private foreign companies by government enterprises. In addition to improved genetic stock, feed additives, feed formulation technology, and pharmaceuticals are being imported.

Imported breeds and inputs have created a major new industry in poultry meat, which went from 1 million tons in 1980 to 6 million tons in 1995, valued at approximately $6 billion. The egg industry was already important before imported inputs came in: 3 million tons of egg were produced in 1980. But the new breeds and confinement management have boosted productivity and output considerably—17 million tons of eggs in 1995 (FAO).

More pesticides are used in China than in any country in the world. Almost all of the active ingredients were developed by private research outside China. As mentioned above, foreign firms account for 20 to 25 percent of the value (if you count the intermediate chemicals used in pesticide production), and the rest is sold by Chinese firms.

There have been no overall evaluations of the impact of pesticides on production, but companies provided some examples of the potential impact. For example, AgrEvo claims that its wheat herbicide, Puma, increases yields at least 10 percent and sometimes 20 to 30 percent in wheat yields on about 1 million hectares which did not use herbicide previously (or used 2-4D, which did not kill grasses). If the average wheat yield is 300 kg/mu, the increase in yield 10 percent, and the price of wheat Y1.1/kg, the increased value of wheat per mu will be Y33. The extra cost is Y2-3/mu. The net benefits are Y30/mu.

A few field crops have benefited from foreign varieties. The most high-profile foreign variety is Monsanto's and Delta and Pineland's genetically engineered cotton, an American cotton variety genetically modified to contain the Bt gene that makes it resistant to bollworms. It was planted commercially for the first time in 1995 on about 200,000 acres in Hebei province. Yields in 1994 on 10,000 acres grown for seed were 1,125 kgs.lint/ha while the provincial average was 825 kg/ha (Monsanto). Not only are yields higher but insecticide applications are reduced from at least 12 to one and the fiber is superior in strength and color to the local varieties. Seed cost goes from Y25/mu (5kg/mu * Y5/kg)—for purchased seed; most farmers keep their own seed—to Y52.5/mu (1.25kg/mu * Y42/kg), while the increased benefits will be at least Y288/mu (20 kg * 14.4Y/kg).

Other imported varieties grown commercially are sunflowers in western China and sugarbeets in the north. Approximately 1,000 tons of sugarbeet seed worth about $3 million are imported from Germany annually, which presumably has increased sugarbeet yields.

Vegetable varieties from Taiwan, Thailand, and Japan have been imported for a number of years. Food processing firms have also transferred agricultural technology. For example, Simplot, the firm that supplies partially fried, quick-frozen potatoes to McDonald's in China, is introducing American and Canadian potato varieties and a large number of improved management techniques to improve potato quality. Dole is producing citrus in southern China. BAT is producing tobacco. These companies usually bring in management technology and varieties.

U.S., European, and Japanese farm machinery firms have identified some technology that is appropriate for China's land/labor ratio. John Deere sold the design for a combine harvester to the Tianjin Tractor Factory. It has been produced for 10 years. In the early 1980s, Luoyang Tractor Works adopted tractor technology from Fiat/New Holland. More recently, New Holland and John Deere have sold a few large imported tractors. In addition, in the last few years, Kubota and Yanmar have started selling small rice harvesters in southern China.

Potential Impact of Foreign Technology

Are Chinese farmers missing out on technology because of government regulations and policies? It appears that they are, and we identify some of those missed opportunities here.

There is evidence from government trials that foreign technology could make major contributions to yields and quality of a number of major crops. Hybrid maize varieties from DeKalb have yielded 10-15 percent more than the check varieties in official yield trials, now that the government is testing at U.S. plant densities. In the past, when tests were conducted at the lower Chinese plant densities (but higher seed rates), the Chinese hybrids always yielded more. DeKalb has had two hybrids officially approved for use in China (DeKalb, 1997). Other companies that have corn hybrids equal good or superior to DeKalb's elsewhere in the world still have been unable to sell any seed in the Chinese market. For example, Pioneer, the world's leading seed company, has been trying to get into China for years and still has permission only to do research, not to sell its hybrids.

Potato production in general has increased rapidly in the last few years—faster than demand—with the result that prices were very low in 1995. Simplot, the supplier of potatoes to McDonalds, has been working on high-quality potato production for french fries here since 1986. After some early failures with American varieties, they are gradually increasing the contract production of several local varieties and one American variety. Pepsico was also working to improve potato quality and yield to produce good crops for chipping.

Private and public research programs in North America and Europe have invested a lot of money on improving rapeseed (canola), sugarbeets, and soybeans for climates similar to China's, so China should also be able to take advantage of these foreign technologies.

Most of the popular pesticides in world are available in China, although some of the newest are not. What Chinese farmers are missing from pesticides is the tacit knowledge—the information on efficient use of the chemicals—which should be provided, but often is not, when the chemical is sold. Local companies may not know about the best practices, and foreign companies have little incentive to educate people about a product that someone else is selling. The result is overuse of herbicides, which reduces crop yields, and overuse of chemicals, which wastes chemicals, creates environmental problems, and may encourage the development of resistance to the chemicals.

Biotechnology offers the potential to reduce insecticides and fungicides and increase yields of crops and productivity of livestock. In the United States and Latin America, where transgenic crops are grown on almost 30 million ha (James 1998), biotech has produced herbicide-resistant soybeans and corn (which increase the efficiency of herbicide use), Bt corn (which is resistant to borers), and corn with enhanced protein and oil quality for animal feed and human consumption. All of the international companies with major investments in agricultural biotechnology—Monsanto, Pioneer, DuPont, Novartis, and AgrEvo—have offices in China and (except Pioneer) sell other products there, but they are all waiting to see whether Monsanto is successful or not before making major investments in biotechnology.

Farmers are the ones who suffer from policies and regulations that restrict biotech. Despite the success of Monsanto's transgenic cotton in Hebei, transgenic cotton in 1998 still had not been approved by the Biosafety Committee for use in other provinces. Until this is done the only source of Bt cotton will be smuggled seeds from Hebei. These seeds may or may not be the real thing. Even if they are the real thing genetically, they may not do well because they have not been delinted and treated with pesticides like Monsanto's seeds. Thus, Chinese farmers outside of Hebei will be getting less yields, have greater pesticide costs, and create more damage to the environment than they would with transgenic cotton. In addition, Chinese farmers are missing out on the transgenic maize, soybeans, potatoes, and canola that have been commercialized elsewhere.

Determinants of Research and Technology Transfer

As mentioned in the introduction of this chapter, the main characteristic of Chinese private agricultural research and technology transfer that needs to be explained is the low level of private sector research and technology transfer. Government restrictions on the role of the private sector are the major factor explaining the limited private research. Uncertainty about the ability of foreign firms to control their proprietary technology due to weak intellectual property rights and uncertainty about rules on foreign ownership of joint ventures have also played an important role.

According to neoclassical economic theory, firms seek to maximize expected profits. The expected profits to a firm from investing in research are a function of the expected benefits and costs of research and development of a commercial product. The expected benefits will be based on the expected size of the market, the share of the market that they can capture, and the expected price of the new product. Firms will calculate the expected market size based on current market size and growth rates for this industry. They will estimate their expected share of the market by looking at their current market share in the industry, the strength of intellectual property rights in the country, and technical means of protecting their product from copying. The expected price will be based on current prices of similar products plus their ability to keep other firms from copying the product and competing against them. Economists call this ability to capture economic gains from research appropriability.

The expected cost of the private research needed to develop a new commercial product depends on the state of technology in China and elsewhere in the world. The salaries and benefits of scientists, engineers, and technicians will be important components of research costs. In addition, laboratories, experiment stations, and the supplies to run them are important expenses of research. The availability of technology from public institutes, which can be adopted or modified through local research, can substantially reduce the research needed to develop a commercial technology. Imports of technology, which can then be adapted to Chinese conditions, can also be an important stimulus to local research and can benefit farmers directly. Breakthroughs in basic science such as the advances in biotechnology can lead to a whole new set of possible technologies from transgenic crops, to new veterinary medicines, and plant and animal disease diagnostics.

Market Size

The major factor limiting the size of private investment is the continued dominance of state owned enterprises (SOEs) in the agricultural input production and supply. Only SOEs are allowed to sell seeds of major field crops; foreign firms are allowed only 20 percent of the pesticide market, and, until the late 1980s, were not allowed in at all. Seed of the major grains and cotton is the least liberalized input industry, followed by fertilizers, pesticides, and agricultural machinery. Food processing has had considerably more commercialization. In agricultural production, poultry, swine and fisheries present the greatest opportunities for commercial enterprises, with grain production having the least opportunity.

A related factor is that prices and the quality of most of the inputs produced by SOEs is low, which pushes down margins even on higher quality products. For example, the ratio of hybrid maize seed to grain prices in China is 6 to 1 while in the United States, it is more than 30 to 1. Local suppliers attribute the low prices to overcapacity and competition between SOEs in most industries. Foreign companies argue that many of the local inputs are of low and variable quality and that some, such as pesticides, are produced in ways that are dangerous to workers and the environment.

China is a market that major international agricultural input firms cannot ignore—it is the largest or next to largest market in world for hybrid seeds, pesticides, fertilizer, agricultural machinery, layers, swine, and other inputs. Some of these markets have been growing extremely rapidly, other have not (table H-3). There has been slow growth in seeds and declining production of large tractors. Herbicides have grown rapidly but not insecticides. Poultry and swine genetics and feed have grown very fast. Most large multinationals feel they need to have some sales and often some exploratory research in China, but government restrictions limit their growth.

The pattern of growth in investments in agricultural research and technology transfer also provides evidence of the importance of government restrictions as the major constraint on private research. As the government gradually opened industries to foreign firms, international companies came in. Thus, the earliest companies were the poultry genetics companies that were allowed in during the early 1980s. Pesticide firms were allowed in starting in the late 1980s and early 1990s. The latest firms are the seed companies. It is still not clear to what extent the government will allow them to operate.

A factor influencing the demand for quality inputs is the commercialization of agricultural services. Since every institution, whether it is research, extension, or regulatory, has to earn money to supplement the meager government contribution, unbiased research, extension, or regulation is increasingly rare. This makes it difficult for farmers to decide what technology they should buy. The seed stations, which were recently separated from the government seed companies so that they could do unbiased regulation of seed quality, are now going into the seed business with private firms. The government's Plant Protection Service (PPS) is supporting itself with sales of whatever pesticide gives them the largest profits. It is not likely that these organizations will give unbiased advice on plant varieties or pesticides. This increases farmers' risks and makes them less likely to invest in new technology.

Appropriability

The second most important factor (after restrictions on private participation in markets) leading to low investments in research is the lack of effective intellectual property rights (IPRs). IPRs and technical means of appropriating the gains from research have increased recently. There is still the perception, however, that IPRs are weak, and that perception has been reinforced by some high-profile cases like the copying of DuPont's sulfonylurea herbicides in the early 1990s, despite guarantees by the Ministry of Chemical Industries that no copying would be allowed.

The industries in which private research is greatest—chemicals, seeds, and poultry—are those with technical means of protecting their technology. Almost all of the plant breeding and screening research by private firms in China is on crops in which hybrids are sold commercially in China—corn, sunflower, sorghum, rice, sugarbeet, and cotton—because hybrid plant varieties cannot be easily copied by farmers or competing seed firms if the parents of the hybrid are kept secret. Rapeseed and wheat hybrids are not commercially grown in China, but companies are working to develop them. Cotton is the only crop in which private firms are working on varieties in China. In the case of cotton, the companies hope to control copying by buying back all of the seed. In the agricultural chemical industry, some chemicals (like seeds) are much more difficult to copy than others. Thus, some of the most profitable chemicals for foreign companies in China have not been widely copied because their active ingredient is a very complex molecule and/or the formulation is difficult to copy.

In the seed industry, the government-imposed market structure makes it difficult for local entrepreneurs, and even government-owned enterprises like seed firms set up by research institutes, to make money from developing new hybrids. Since government regulations give county seed firms a monopoly on production sales of hybrid seeds other than vegetables, research institutes or private firms have to turn their inbred lines over to the seed companies to produce the seed. Once they have done that, the firms can reproduce the hybrids with no problem and have no incentive to pay the agreed-upon royalties. There are no plant breeders' rights or patenting of hybrids, and it is difficult to get the courts to enforce contracts. Most government rice breeders we interviewed said that companies did not pay on the hybrid rice cultivars from the government breeders (see Pray, Rozelle, and Huang, 1998).

Legal protection of IPRs on pesticides has been strengthened recently, which stimulated investment in this industry. Three changes have taken place: stronger legal protection of intellectual property rights, better enforcement by courts and the administration, and the ability to set up joint ventures with foreign majority ownership. The Chinese patent law went into effect in 1985. New chemicals and pharmaceuticals were first protected by invention patents in 1993 for new chemicals which were patented outside of China in 1993 or later. In addition, in 1993, "administrative protection" was provided by the Ministry of Chemical Industry for pesticides patented elsewhere from 1986 to December1992. The protection lasts for 7.5 years.

Plant varieties are now protected by the 1997 plant breeders' rights law, but the office for taking applications had not yet opened for business in 1998.

Enforcement of IPRs has improved. There are two ways of enforcing IPRs. The first is administrative. If a violator is found, the Ministry of Chemical Industries (MCI) is informed, and it can withdraw the producer's permits to operate and close down the factory. Some foreign companies reported that they were quite happy with MCI because it responded to their needs. Others said that almost nothing had changed.

The other way of enforcing IPRs is through the court system. Foreign companies have started to win patent infringement proceedings in Chinese courts. No victories on patent infringement in the pesticide industry were reported during this study. However, Cyanamid recently won perhaps the first ruling in favor of a foreign agricultural chemical company on trademark infringement and fraud. In this case, a firm attempted to sell a Cyanamid chemical with the Cyanamid trademark claiming that it had been authorized to do so by the Cyanamid headquarters. Cyanamid was able to show that its headquarters had not authorized the Chinese company and that the product being sold was not up to Cyanamid's specifications or the specifications on the label. The court ruled that the Chinese company had violated Cyanamid's trademark and had fraudulently sold this product. Cyanamid received a lot of useful publicity from the case, which it hopes will deter copying in the future.

Allowing firms to be majority shareholders in joint ventures has increased their ability to appropriate benefits. In most industries, foreign firms must have a Chinese joint venture partner. Thus, they must share part of the returns with their Chinese partner. Local ownership requirements, however, have been relaxed. In the late 1980s, it was impossible for livestock breeders to have a wholly owned subsidiary in China. Now, some have been allowed to set up a representative office, and a few companies are being permitted to set up wholly owned subsidiaries. In the early 1990s, pesticide firms were allowed to set up majority-owned joint ventures. In the mid-1990s, a number of seed firms were able to do the same thing.

Some of these gains are threatened by new regulations, however. In the seed industries, according to 1997 regulations, foreign firms wishing to produce and sell seeds of the major grains, oilseeds, and cotton in China have to be minority shareholders. This means that they lose control over their most valuable asset—their technology. So far the Chinese Government has not enforced this regulation. If it decides to do so, the few seed companies now are in China may well leave or reduce their investments.

There is a similar threat in the agricultural chemical industry. A 1996 law says that joint ventures must produce in China the active ingredients of their pesticides and the intermediate chemicals that are inputs in the production of the active ingredients. This would make the technology for producing the active ingredient much more easily available and increase copying. So far this regulation has not been rigorously enforced either. If it is, agricultural chemical companies will be even more hesitant about investing in China.

Technological Opportunity— The Cost of Innovation

Government policies and scientific breakthroughs and geographic conditions have provided a number of technological opportunities and reduced the cost of doing research, which leads to more private research. This is in contrast to markets and appropriability in which government policies, while increasingly favorable, still are major constraints to private research.

The cost of research and technology imports by private firms is quite low because much of China's agriculture is in temperate regions similar to regions in the United States and Europe. Thus, the cost of developing and introducing new technology is primarily the cost of testing and occasionally adapting foreign technology to Chinese conditions. Most research by private seed firms, private pesticide firms, and poultry and swine breeders is very applied or is simply testing technology that was developed in the United States, Europe, and Japan. For example, American and European high-yielding hybrids and varieties with higher quality grain or fiber of cotton, maize, sunflower, sorghum, sugarbeet, and possibly rapeseed are the basis of private seed industry research. As mentioned above, most research by pesticide firms is testing the effectiveness and environmental impact of chemicals new to China but commercialized elsewhere. All of the poultry research is based on western breeds of poultry.

In addition to the limited need for adaptive research, the costs of research in China are low because of the low salaries and large numbers of well-trained Chinese scientists. Income at the best Chinese research institutes has risen dramatically over the last 10 years, but it is still between $150 and $500 per month. China has more agricultural scientists than any country in the world. Research reforms, which forced research institutes to earn money through commercial enterprises, have made the institutes more eager to contract work or go into joint ventures with private firms. The reforms have not been successful in keeping researchers' incomes near private firms' salaries. Thus, some of the best scientists are available to work in private research or in management positions in private firms. If the current privatization of housing takes place, even more government scientists will be willing to move to the private sector since access to housing was one of the main advantages of government jobs.

The recent reforms of the Chinese public research system have reduced the cost of starting private research and technology transfer companies in China. Chinese research firms, which now have to earn money from their commercial enterprises, have developed a number of small seed firms and some larger ones. In hybrid maize, Mr. Li Denghai, a government maize breeder, has established a commercial (but state-owned) hybrid seed firm in Laizhong City in Shandong province. In hybrid rice, the Hunan Hybrid Rice Research Center has established a joint venture with the U.S. firm, Ricetec, to work on hybrid rice in the American and Chinese markets. The reforms also made it easier for foreign firms to enter the market. Many of them were able to hire managers and technical staff from the Vegetables Research Institute of the Chinese Academy of Agricultural Sciences, which has one of the most successful commercialization programs.

While the breakthroughs in biotechnology have been a major stimulus to private research in the United States, Europe, and Japan, biotech has had only a limited impact on private research in China so far. Genetic engineering has stimulated some research by Monsanto and its partner Delta and Pineland. As of June 1998, they were the only private firms that had applied to the government biosafety committee for permission to do field tests of genetically engineered crops.

Biotech may be an important stimulus to private research in the near future, depending on Monsanto's experience with Bt cotton in Hebei and elsewhere. As described above, Monsanto has managed to get through the regulatory system (plant variety tests and biosafety committee). Monsanto sold enough seed to plant 200,000 acres in Hebei Province in1998. There are reports that farmers in provinces near Hebei are also growing Monsanto's Bt cotton without permission. The question now is how much Monsanto will be able to sell in the future and at what price and whether farmers will have multiplied a lot of this seed themselves. Agrevo and Novartis are watching this experiment carefully before they decide to invest in biotech in China.

The main factor reducing technological opportunity in China is the policy that restricts imports of foreign technology. Recent studies in Brazil (Johnson, 1998) and India (Basant and Fikkert, 1996, Fikkert, 1995) have shown that imported technology increases the productivity of industry and also stimulates private research or replaces research that is re-inventing the wheel. China restricts the imports of agricultural inputs that embody technology (seeds, pesticides, parent stock of poultry, and machinery) while attempting to import the technology (new breeds of crops, poultry and swine, active ingredients and intermediates of pesticides, and designs of farm machinery) through government institutions. This prevents potential Chinese entrepreneurs from working with the latest foreign technology as agents or employees of the foreign firm, improving the technology, and building businesses based on their improvements.

The commercialization of public research and agricultural services poses several negative impacts for the development of private research. First, declining public funding for research could reduce future opportunities for private firms to develop technology. Biotechnology is still doing well with government funding from the Ministry of Agriculture and a number of other Ministries, but other less trendy areas of agricultural research like enhancement of genetic stock of major grain crops like wheat and soybeans are languishing. In addition, research that has no immediate payoff to research institutes is neglected, like crop management research, even though it can increase farmers' returns from using modern inputs, thereby increasing farmers' welfare and demand for modern inputs.

A second problem is that there is more uncertainty about whether good new products will be approved for commercial use or not. The government scientists and officials who establish agricultural policies and make decisions about which plant varieties, chemicals, genetically modified plants etc. will be approved for use by farmers, are the same people whose incomes depend on these decisions. Thus, they can use regulations and policies to block competition from competitive local or foreign companies. A number of foreign seed firms reported difficulty getting their new hybrids officially approved, perhaps due to the fact that the hybrids are not good enough or perhaps because of biased officials.

Conclusions and Policy Options

So far private companies are not filling the gap in technology supply left by the decline of public sector research. Foreign firms are doing a small amount of research in China, and local commercial enterprises, whether they are owned by the public or private sector, appear to do even less research. As a result, the amount of private research in China is low relative to the size of its agricultural GDP and relative to other countries in Asia (table H-6). The low level of investment by local agribusiness firms in agricultural research is in dramatic contrast to India, where local firms do 70 percent of the private research, Malaysia, where local research is 90 percent of the private research, and Pakistan, where local firms account for 69 percent of the research (see applicable country case studies).

The impact of private research and technology transfer has also been very limited. In the few industries where foreign firms have been relatively free to supply inputs (for example, the poultry industry), they have made a major contribution to output growth. New foreign pesticides appear to have had a positive impact on the environment, workers' safety, and agricultural productivity. In other input industries that have more restrictions, such as the seed industry, there is evidence that foreign technology could make a contribution but so far has not.

The major constraints to private research and technology transfer are government policies. The potential markets for improved inputs and food are huge. The technological opportunities are great: firms can build on previous research in other temperate regions of the globe and in the Chinese public sector and research inputs are relatively inexpensive. Thus, if the government wants to encourage private research, it has to allow the private sector a bigger share of the markets and strengthen firms' ability to appropriate the gains from research. Table H-8 summarizes the policy and regulatory constraints that face foreign and Chinese firms. The last column lists some suggested reforms.

Why the Limited Amount of Private Research by Foreign Firms?

The main reason for the small amount of research and technology transfer has been government monopolies or near monopolies on production and distribution of most agricultural inputs and specific government

Table H-8—Policy constraints on private research and possible reforms

	Constraints on local enterprise	Constraints on foreign research and tech transfer	Possible reforms
Markets	State-owned enterprises' (SOE) monopoly on hybrid seed production & sale.	SOEs monopoly on hybrid seed production and sale.	Eliminate SOE monopolies
	Limits on who can import foreign inputs and how much can be imported.	Imports and foreign production restricted to 20% of pesticide Only CASIG can import seed. Imports of N-fertilizer limited.	Allow more imports of technology by private and foreign firms.
	SOEs have large share of production and sales in fertilizer, machines and other inputs		Continue to reduce government subsidies to SOEs.
	Regulation of new technology arbitrary or biased	Regulation of new technology arbitrary or biased	Reform funding of regulatory system & ensure regulators have no conflict of interest.
Appropriability	Difficult to enforce patents	Difficult to enforce patents	More government resources for enforcement.
	SOE monopoly of seed production	Joint ventures required; must be minority owner.	Allow foreign majority ownership.
	Plant breeders' rights passed but office not open	Plant breeders' rights passed but office not open	Start enforcing plant breeders' rights.
Technological opportunity	Input imports limited and foreign research limited.		Reduce barriers to input imports and research by foreign firms.
	Public research funding is declining.		Greater funding for research to assist local firms.
Other	Lack of capital for new firms		Government-assisted venture capital funds.

restrictions on foreign firms. For example, seed production and seed sales of grain, oilseed, and cottonseed must be by state-owned enterprises. Firms that have majority foreign ownership are legally prohibited from operating in the seed industry, with the exception of vegetable seed, and are legally prohibited from producing pesticides. No foreign companies have been allowed to set up their own network of dealers to sell inputs directly to farmers.

The second most important factor leading to low investments in research is the weakness of intellectual property rights. IPRs have been strengthened through extension of the law to cover new areas like pesticides and plant varieties, and enforcement through the courts and by administrative means has improved. However, foreign (and local) firms still have great difficulty enforcing their patents against infringement.

A third factor is the restriction on imports of agricultural inputs. Imports of agricultural chemicals are subject to quotas, and imports of some inputs such as hybrid seeds and the parent stock of chickens are virtually banned. Import restrictions limit the technology that firms can profitably bring in to technology that is profitable to produce in China. This limits what they will bring in to things for which there is a large market.

Why Limited R&D by the Chinese Input Industry?

Agricultural research by Chinese commercial firms could develop from four sources: state-owned enterprises (SOE), spinoffs from foreign firms, government agricultural research institutes, and individual entrepreneurs. Firms of each type face difficulties.

Some industries are still reserved for SOEs and face other government restrictions. For example, only government-owned companies are allowed to sell hybrid seeds and seeds of major field crops.

Weak intellectual property rights make spinoffs from SOEs, foreign firms, and government agricultural research institutes difficult. The government agricultural research institutes have the potential to evolve into commercial input firms. Entrepreneurs are ready to leave SOEs and foreign firms and start up new firms. However, limited intellectual property rights, which still do not effectively protect their plant varieties, new pesticides, and other products, means that profits are uncertain at best.

Commercialized research, extension and regulation have few resources and little incentive to help private research. Public research, extension, and regulation could stimulate, verify, and push new technology developed by local private firms, but reduced public funding for these institutions often means that the public sector cannot help.

Restrictions on imports of agricultural inputs prevents potential Chinese entrepreneurs from working with the latest foreign technology as agents or employees of the foreign firm, improving the technology, and building businesses based on their improvements.

SOEs and the related research institutes are reducing their research because the SOEs face overcapacity, overproduction, low prices, and too many employees. It is difficult for them to justify investments in research when their profits are low and they are laying off other staff. However, this means that they will have less research capacity when they are commercialized, and there will be fewer opportunities for spillovers to local private firms.

Capital for high-tech spinoffs from SOEs, foreign firms, and government agricultural research institutes is difficult to find. This is due to the combination of weak intellectual property rights, the weak capital markets in China, and government sources of capital, which are often not available to entrepreneurs who want to compete against the SOEs.

Despite these restrictions, a few small organizations like the maize seed company of Li Denghai and the rice seed company of the Hunan Hybrid Rice Research Institute are emerging as possible competitors to the SOEs and MNCs. In addition as mentioned above, some SOEs like the chemical firm Shanghai Zhongxi and the newly merged Shanghai Diesel Engine Research Institute and Shanghai Diesel Engine and Tractor Industry Company are investing in research.

Policy Alternatives To Encourage Private Research

A variety of reforms could be used to encourage more private research and technology transfer.

Dismantle SOE monopolies in the agricultural input industries. Reforms resulting in the dismantling of the SOE monopolies in production and marketing of many input industries have made considerable progress. Continued progress can lead to more private research.

Encourage foreign direct investment. Restrictions on foreign firms in the input industries reduce competition and at the expense of farmers. Progress has been made since the early 1980s when no foreign firms were allowed. Now they can come in but they must have local partners. However, in the seed industry the government took a step backward in the late 1990's when they issued new more restrictive regulations on foreign participation in the seed industry on the major field crops like grains and cotton. Agricultural chemicals also have had new restrictive conditions for foreign investment placed on them in the last two years.

Remove barriers to imports of agricultural inputs. The quotas on pesticide imports and bans on other imports restrict competition and opportunities for choice for farmers. By gradually reducing these barriers, more and improved inputs will become available for farmers.

Enforce intellectual property rights. Agricultural chemicals, biotech, and seed industry research would be strengthened by stronger IPRs. All agricultural chemical companies agree that the IPR situation has improved greatly for agricultural chemicals since 1990, but foreign companies would like it to become even stronger. Plant breeders' rights have been made into law but have not yet been enforced. The immediate future of private plant biotechnology research and products depends on Monsanto's experience with Bt cotton in Hebei and elsewhere. IPRs to protect this technology will be necessary. Plant breeders' rights and patents on biotechnology products need to be enforced for Monsanto and Chinese firms to be successful.

Rationalize regulations of new technology. A major problem is emerging in the provision of unbiased regulation of new products. Regulatory services cannot be expected to be unbiased if they are dependent on the industries they are supposed to regulate for a large share of their income. Regulatory services have to be financed well enough that they can hire and keep good people without being dependent on the industries they are supposed to advise and regulate for a large share of their income. Given the commercialization of the government's regulatory system, China's effort in this area would benefit by changing from mandatory variety testing and seed certification to voluntary testing and registration of varieties used by India and the United States.

Make capital available to small research-based agricultural input firms. The government financial system could set up something like a venture capital firm to assist new technology-based enterprises to get established.

Ensure the continued strength and independence of the public research system. Since private research is not taking up the slack for the decline in public agricultural research funding, one option is for the public sector to continue to supply farmers with new technology. In addition, services such as the provision of germplasm and unbiased testing of new technology that would strengthen private research could be provided. These activities require more funding and reforms, which are discussed in other papers (Rozelle, Pray, and Huang, 1998)

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List of Tables

Table H-1. Growth rate of China's agricultural economy by sector and selected agricultural commodities, 1970-96. 138

Table H-2. Projected annual per capita food consumption under baseline scenario in China, 1996-2020. 139

Table H-3. Characteristics of agricultural input industries 140

Table H-4. Foreign direct investment and imports by industry 141

Table H-5. Research and development by industry, 1995 143

Table H-6. Private and public research and research intensity in Asia, 1995. 143

Table H-7. Chinese agricultural and food invention patents, 1985-97. 145

Table H-8. Policy constraints on private research and possible reforms 152