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FOOD SECURITY OPTIONS

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Contents

This report uses *Hong Kong* when referring to the Hong Kong Special Administrative Region, People's Republic of China.

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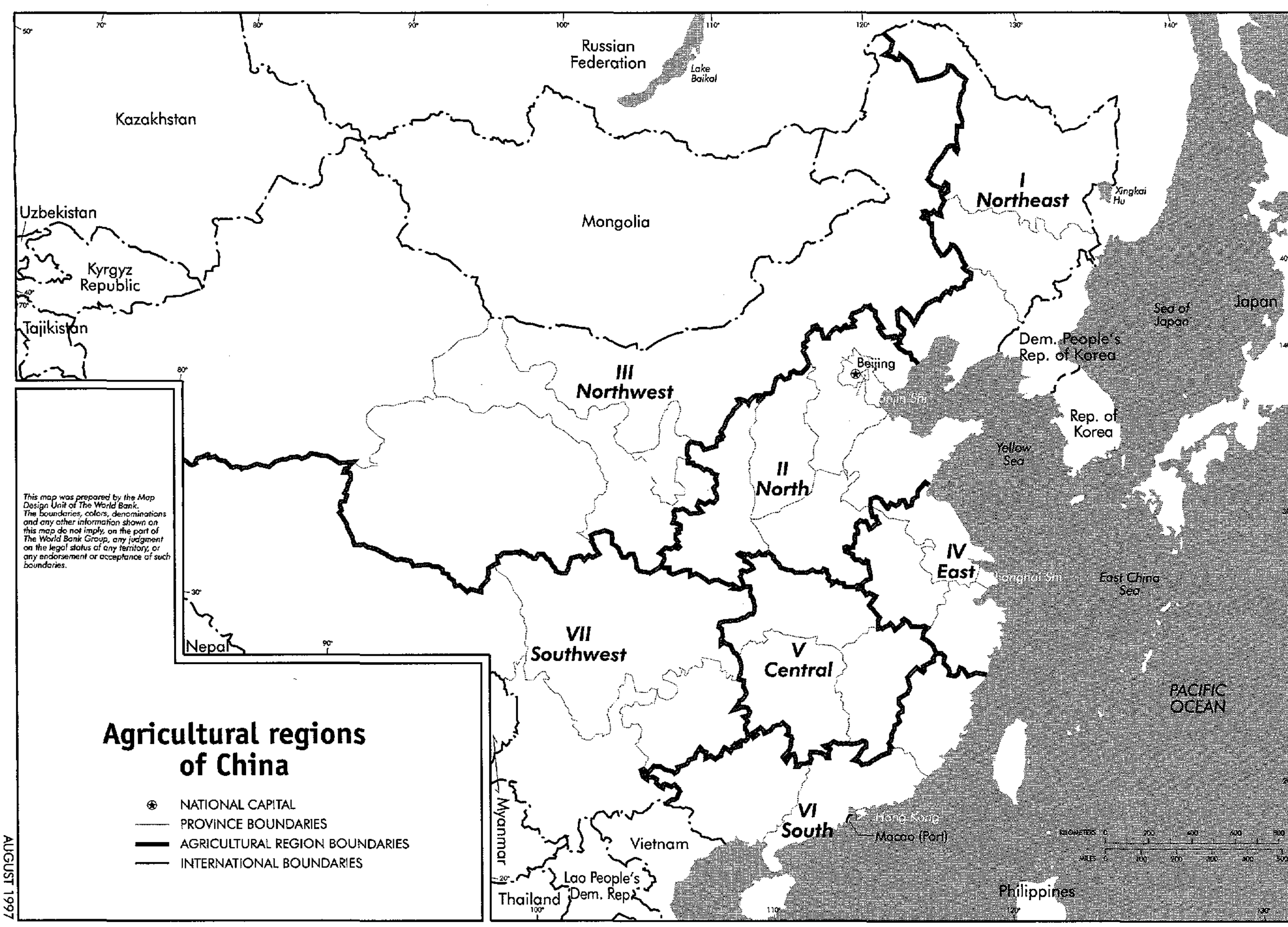
The book was edited by Bruce Ross-Larson, designed by Kim Bieler, and laid out by Glenn McGrath and Laurel Morais of the American Writing Division of Communications Development Incorporated.



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Overview

China can remain food secure over the next two to three decades and domestic food production will largely keep pace with population growth—if it can overcome the obstacles to growth in agriculture and infrastructure and implement several policy reforms. An objective of the government's food policy is to maintain 95 percent grain self-sufficiency. But this study shows that greater integration with international markets would permit food security at a lower cost—and that cereal self-sufficiency could decline to 90 percent. This conclusion is consistent with the expectation that China will join the World Trade Organization and will rely more on market forces to trigger investment, production, and consumption decisions. As a result, China and China's trading partners will benefit, through lower production costs and higher farm incomes, as each country's comparative advantage is exploited. China is also likely to attract more foreign direct investment and import more technology.

The best estimate of China's grain demand in 2020 is about 697 million tons of trade grain (608 million tons of milled equivalent). Of this, China will likely produce 90 percent and import the balance—about 60 million tons. The major grain-exporting countries can readily supply this amount without a large price increase. But China will have to invest heavily in port facilities and bulk logistical systems—otherwise, imported grain, if handled by the current outmoded systems, will be very costly. And meeting 90 percent of China's grain demand through domestic production will be achievable only if China increases its investments in infrastructure, agricultural research, and land and water development. If not, imports will have to increase. And even with large investments, irrigation is likely to become a serious constraint to continued growth in agriculture.

Among the required initiatives:

- Improve agricultural research and extension—and balance fertilizer application.
- Improve the efficiency of water distribution and increase aggregate irrigation water supplies, including reuse and water transfers from the Yangtze to the Yellow River Basin.
- Reclaim and develop land to maintain the current stocks of arable and irrigated land and increase the efficiency of multiple cropping.
- Develop dedicated and integrated grain and oilseed transport facilities.
- Reduce government intervention in the cereal and fertilizer sectors, encourage market-determined prices, and open marketing and trade competition.

Since the early 1960s China has made remarkable progress in national food security, though household food security remains a problem for low-income groups. Through the late 1960s and 1970s, large investments in agricultural research led to the production and adoption of new technologies. Fertilizer production and application increased rapidly—at an average of 18 percent annually between 1962 and 1980. New crop varieties boosted grain yields by an average of 5.1 percent a year. Over the same period the irrigated area expanded by one-third (by 11 million hectares).

Then in the late 1980s and early 1990s agricultural research investments declined, and growth in fertilizer use slowed. Pricing reform in the mid-1990s brought domestic grain prices close to international levels, resulting in record outputs. But marketing reform to allow greater private participation was rescinded.

"Average" food consumption is relatively high. Per capita cereals consumption is among the world's highest, and consumption of vegetables and livestock products is similar to that of countries with much higher incomes. Continuing income growth will lead to further dietary changes, but because consumption of "superior" foods is already high, these changes will be less than current income elasticities imply.

Consumption and requirements

Cereal requirements for all uses will be about 697 million tons of unmilled grain in 2020, just a 50 percent increase over twenty-five years (table 1).[1] And with adequate investments in agriculture and infrastructure, domestic production should reach about 636 million tons by 2020, requiring about 60 million tons of wheat and coarse grain imports.

Domestic production

Projections of domestic grain production are based on investments in agricultural research to maintain total factor productivity growth, water resources to expand irrigation water supplies by 0.5 percent annually, land reclamation to maintain the existing cultivated land base, and domestic fertilizer manufacturing, coupled with foreign exchange availability, to provide balanced fertilizer supplies. It was also assumed that policies would change to encourage competitive prices and efficiencies.

Irrigation water supplies would limit production in the northern corn and wheat areas, but in the more

TABLE 1

Estimated cereal consumption and total grain requirements in 2020 (milled)

	Rice	Wheat	Coarse grain	Total
Per capita consumption (kilograms)	105.7	99.4	53.2	258.3
Direct cereal consumption	66.5	51.5	23.1	141.1
Manufactured food consumption	39.2	47.9	30.1	117.1
Requirements (million tons)	208.6	174.8	224.5	607.9
Direct and processed consumption	150.9	142.5	75.0	368.3
Feed grains	46.3	21.6	138.2	206.1
Seed and losses	11.5	10.7	11.3	33.5

Source: World Bank data and staff estimates.

water-abundant south, supplies would be sufficient to expand rice production. Consequently, rice supplies will be more than adequate to meet direct consumption needs, and rice will be used increasingly as a feed grain—primarily the hybrid rice varieties that are considered inferior as a food grain.

Based on these assumptions, domestic grain production in 2020 is estimated at 667 million tons under the optimistic scenario and 636 million tons under the "most likely" scenario. The supply-demand balance indicates wheat and coarse grain deficits requiring imports of 30 million tons of wheat for food and 30 million tons of coarse grain for feed and industrial uses.

International supplies

A survey of unused production capacity in the traditional exporting countries indicates ample scope to expand production enough to meet China's incremental requirements and those of other importing countries without major price increases. For example, in 1996/97 world grain production expanded 7.5 percent in response to higher prices, but for the five largest exporters production increased 20 percent, and for Argentina, 40 percent. Long-term estimates of world cereal production range from 2.7 billion tons for 2020 (Rosegrant 1995) to 3.1 billion tons for 2030 (Alexandratos 1997). The second estimate had a base case for world trade of 400 million tons in 2030 but that could be higher if China imports more than 50 million tons. The greater difficulty will be China's capacity to import this much grain. Without large investments in deep-water berths, port handling equipment, transit storage, bulk grain transfers, and bulk rail equipment to improve grain handling efficiency, handling costs will be very high.

Investments

To ensure that agricultural productivity continues to grow, China must invest more in research. Since 1978 agricultural growth has averaged 6.1 percent a year, and agricultural research has contributed more to growth than any other factor. Although nominal and real research budgets have increased over the past fifteen years, de facto research budgets have declined by several measures. Unless there is a continuing flow of new technology, agricultural growth will lag behind the general economy, and food imports will be larger. What investments in agricultural research would be optimum is difficult to determine. But it is essential to reverse the declining trend.

Because water scarcity limits agricultural growth most, large investments are required to develop additional water supplies—an increase of at least a 0.5 percent a year in supplies—and to transfer water from the surplus south to the deficit north. Public investments are needed to improve irrigation water distribution systems, and private investments are needed to improve on-farm use. Irrigation is a residual water user after other requirements are met, and in the future more water will be diverted from agricultural to urban and industrial uses. Wastewater treatment and water recycling are essential to expanding irrigation water supplies and producing uncontaminated food supplies.

China must import more potash to balance fertilizer application. The constraint to balanced fertilizer application—whether poor policies, monopolistic market structures, or lack of farmer knowledge—must be quickly identified and resolved. Balanced fertilizer application would immediately increase grain yields by 12 to 15 percent—vegetable yields even more. For example, if China had imported and applied another 6.7 million tons of potash in 1995 at an approximate cost of $1.5 billion, the value of incremental grain production would have been more than $9 billion, and the value of all incremental crop production would have been about $18 billion.

China imports 20–25 percent of internationally traded fertilizer to meet about 30 percent of its fertilizer nutrient needs. In 1995 about 36 million tons of fertilizer (by nutrient content) valued at 125 billion yuan were applied to agricultural crops, representing the primary agricultural cash input. But poor application methods and low-quality fertilizers make fertilizer use inefficient and crop production costs unnecessarily high.

International joint ventures in raw material mining and fertilizer manufacture could resolve some of the investment financing constraints, accelerate fertilizer plant construction, and ensure that the latest technologies are employed. New factories using modern technologies to produce high-nutrient nitrogen and phosphate fertilizers are under construction, and others are planned—but there are delays. Large additional investments in new plants will be required to produce the fertilizer needed and to replace nitrogen and phosphate imports.

Removing obstacles to the reclamation of nonstate commercial land would allow large construction companies to invest in reclaiming and rehabilitating land. About 18 million hectares—barren lands, tidal lands, and wastelands—have the potential to be reclaimed. The cost of reclamation varies from about 15,000 yuan per hectare of barren land to 150,000 yuan per hectare of tidal land. Much of this land is in remote or arid areas, but about 25 percent is in the water-abundant southern provinces.

Official records indicate that cultivated land per capita is very low, but satellite imagery shows the area under cultivation to be 132 million hectares, 40 percent larger than officially reported. About 190,000 hectares of agricultural land are lost annually to urbanization, industrialization, and infrastructure. These losses are more than mitigated by land reclamation averaging about 240,000 hectares annually, but reclaimed land is less productive than the land lost.

Infrastructure investments, though substantial, are insufficient for a dynamic economy. The grain industry suffers from the lack of bulk-handling logistical systems. The volume of domestic grain transported between provinces will probably double over the next twenty-five years, putting substantial pressure on transport capacity. Investment in bulk rail wagons and bulk intermodal transfer systems would improve the capacity to transport grain and increase rail wagon efficiency by increasing use and turnover. The nongrain food industries have better processing and storage facilities but weak transport infrastructure.

With grain imports projected to triple over the next twenty-five years, large investments will be needed in port facilities. Without new facilities, massive vessel congestion and demurrage charges will be incurred. China has only one deep-water berth dedicated to bulk grain handling, with one other under construction. Most grain is now imported on 45,000–50,000 dwt vessels, costing at least $10 more per ton in transocean freight charges than 80,000 dwt vessels. Without more deep-water facilities, trebling imports could add $400 million in transport costs.

High throughput storage is crucial in a bulk grain logistical system. Domestic grain flows between coastal ports now exceed foreign imports and exports, while transfers through inland ports have remained stable. All these flows are transported in bags—requiring slow and costly intermodal transfers. Storage requirements must be carefully calculated to avoid dead storage. Inland waterways, used intensively in other parts of the world for low-cost transport of bulk grain, have been neglected in China because of low rail tariffs. Market-determined freight rates would encourage the development of more efficient bulk transport modes such as barges.

Policies

Today's grain policies may assist in short-term food security, but they distort resource efficiency and impede long-term security. The major grain policy objectives are to maintain 95 percent grain self-sufficiency; increase control over production, pricing, and marketing; and continue controlling stocks and international trade. Reducing government control and permitting more reliance on competitive market forces for determining prices would allocate resources more efficiently and improve long-term food security.

Commercial activities must be separated from policy. Responsibility for the policy functions should go to an appropriately budgeted government entity, knowing that it will incur losses. Government grain enterprises and input suppliers must operate under the same constraints, efficiency incentives, and commercial standards as the nonstate enterprises. Monopoly and monopsony privileges and subsidies currently enjoyed by the state grain bureaus must be discontinued. Countryside procurement restrictions on nonstate enterprises must be relaxed. And enterprises not commercially viable must be allowed to go bankrupt.

If the government wishes to maintain grain reserves, it should designate a government bureau to manage them—and accept that it will incur losses. This could be the bureau responsible for policy functions. Government costs could also be reduced by procuring and storing less grain. The reduction in procurement should be phased, allowing nonstate enterprises to handle a larger share of the marketed surplus. Indonesia and India stabilize grain prices by procuring only 20–25 percent of marketed grain.

To improve the efficiency of water use, including irrigation, the government must raise prices. Low water prices encourage overuse and contribute to low efficiency and to scarcity. Immediate price increases should at a minimum cover short-term supply costs, and government should schedule regular increases to eventually cover long-run marginal costs.

Government should provide incentives for land reclamation and productivity increases. Possible incentives might include income compensation through cultivation leases or parallel development of nonagricultural land for leasing to commercial-industrial interests. Farmers could be offered longer cultivation rights to ensure that they will benefit from terracing and soil amelioration. And allowing farmers to lease land to and from others would permit part-time farmers to lease land to those interested in full-time farming—and increase agricultural output.

Planned trade and single company monopolies should be discontinued. State monopolies plan grain imports and exports far in advance, and although their theoretical purpose is to increase market stability, their transactions have amplified supply fluctuations. Greater reliance on market forces would improve fertilizer import efficiency and enhance grain security.

Note

1. It is difficult to project consumption because of uncertain baseline data, uncertain income elasticity coefficients and income growth rates, and uncertain physical factors, such as feed-to-meat conversion ratios. Within these constraints, future human consumption was estimated using a general equilibrium model. Feed grain consumption estimates were derived separately for various livestock products assuming gradually improving feed conversion rates. Per capita cereal consumption and total requirements were estimated to 2020.

chapter one

Introduction

In 1995 Lester Brown of the Worldwatch Institute forecast that China's grain import needs would likely be between 200 and 369 million tons by 2030.[1] Brown's estimates shocked the research community and alarmed Chinese officials. His estimates also provided the impetus for this study of China's national long-term food security, the latest in a series of World Bank reports on China's grain sector.[2]

China has been famine prone, and as recently as the late 1950s and early 1960s famine claimed millions of lives. That is why government officials remain concerned about grain balances, questioning the reliability of the international market to meet the country's needs. And that is why they have pursued self-sufficiency policies and a program of large domestic grain storage. The strategy is costly and inefficient, but it ensures China's autonomy in domestic grain. Government's distrust of domestic (and international) grain markets has meant pervasive intervention in grain production, marketing, trade, and consumption. (Noncereal food marketing—fruits, vegetables, and livestock and aquatic products—are relatively free of government intervention, and thriving competitive markets have developed.) Grain policy reform and liberalization have been gradual and deliberate, bringing domestic input and output prices close to international levels and consolidating multiple farm-gate prices. But marketing reforms for greater private participation have been short-lived, with frequent retrenchment.

China's economic growth over the past two decades has been remarkable. But its agricultural growth has lagged behind, and within agriculture, output of high-value commodities grew at 9 percent a year or more, while cereals grew at only 3.2 percent.

Rapid income growth has altered food consumption patterns. Per capita (direct) consumption of grains has declined, and consumption of higher-quality fruits, vegetables, and livestock products has increased, particularly among urban consumers. In this process, grain use has increased primarily through indirect consumption (the conversion of grain to livestock products), magnifying the importance of feed grains. As incomes grow over the next two decades, consumption will continue to shift toward higher-value food items. But future consumption growth will likely be less than current income elasticities suggest—because Chinese consumption of "superior" foods is already high.

China is the world's largest cereal consumer, ranking fifth in per capita cereal consumption, and cereals will continue to supply the bulk of calories, as they do in most countries. Expected changes in consumption and production will require China to rely more on the international market to balance cereal supply and demand. Nevertheless, China will be substantially self-sufficient in food. To be otherwise would be prohibitively expensive in terms of transport costs. Estimates of annual import requirements fluctuate between 20 and 50 million tons for the early decades of the 2000s.[3]

This report focuses on how China will avoid national chronic food insecurity, but it also evaluates the storage program and other alternatives to address the problems of transitory food insecurity from drought or other seasonal calamity. It discusses national food security constraints and investments required to maintain total factor productivity growth of 1.0 percent a year. The overall objective is to identify constraints to increased domestic food production and to suggest how China could efficiently achieve food security in the early decades of next century.[4] The study models and projects food supply and demand to 2020. Secondary objectives of the study were to identify and evaluate:

- Factors that most influenced agricultural growth over the reform period.
- Physical and technical constraints and solutions to domestic production increases.
- Policy and institutional constraints to efficient domestic marketing and international trading.
- Infrastructure constraints to domestic and international marketing.
- The potential of the international market to supply incremental grain.

Notes

1. Brown (1995).
2. See, for example, World Bank (1991, 1993a).
3. Fan and Agcaoili-Sombilla (1996).
4. Grain production and consumption were evaluated using a worldwide general equilibrium model to capture all indirect and cross-effects of rapid income growth and international market impacts. The general equilibrium model was supplemented by a physical constraints model, and investment requirements were identified to relieve these constraints.

chapter two

Consumption and Demand

Food consumption levels in China are difficult to establish because data differ from source to source. Cross-section data from the China State Statistical Bureau's annual urban household consumption and expenditure surveys clearly show consumption increases for all food items. But the urban survey time series show just as clearly that per capita consumption of grain has been declining over the past decade, while income has been increasing rapidly—implying that grains may have become an "inferior" food (a good whose consumption falls as incomes rise). These data also indicate that per capita meat consumption has increased only marginally. Rural household consumption trends are similar, but at different levels.

The Food and Agriculture Organization (FAO) uses a balance sheet approach to estimate consumption, deriving consumption as a residual from production and net trade, adjusting for nonfood uses and losses (table 2.1).

TABLE 2.1
China's per capita food consumption
(kilograms per capita)

Food	State Statistical Bureau household survey (1992)	Food and Agriculture Organization balance sheet (1992–94 average)
Grain (cereals)	235.9[a]	224.2
Pork, beef, mutton	20.3	27.7
Poultry	2.4	5.0
Aquatic products	9.2	13.5
Fish	2.0	6.0
Vegetable oil	6.1	6.4
Vegetables	116.9	86.6
Fruit	38.8[b]	28.5

a. Deriving overall grain consumption by combining rural and urban consumption of individual grains yields a national per capita estimate of 216 kilograms.
b. Urban consumers only.
Source: China Statistical Yearbook 1994; FAO 1996.

The major differences in the two estimates are for meat products and vegetables—other differences could be attributed to measurement error. The State Statistical Bureau data capture average household purchases, not food consumed in restaurants, at work sites, or other nonhousehold locations. And the bureau's data for meat and poultry consumption are inconsistent with production data, implying losses that are not credible. Alternatively, the FAO estimates appear to overstate meat production—so consumption is also overstated. Scholars have argued that both estimates overstate cereal consumption by as much as 15 percent.[1]

The balance sheet approach shows an average Chinese diet that is very high in cereal and meat consumption, which is more consistent with diets in countries with much higher incomes. Daily caloric consumption is about 2,730, or 95 percent that of Malaysians, whose per capita GNP is 550 percent greater.[2] Meat consumption, at 32.7 kilograms per capita, is essentially the same as in the Republic of Korea, where per capita GNP is fifteen times that in China. Except for "high fat" pork, which is 70 percent of meat consumption, the Chinese diet is relatively healthy. Fat, oil, and sugar consumption is low—and vegetable consumption high—compared with other Asian diets.

Rice and wheat are 85 percent of direct cereal consumption, but coarse grains are important in some rural locations, particularly in areas unsuited for rice or wheat production. Otherwise, coarse grains are mainly consumed indirectly in meat and livestock products. Grain-to-meat conversion rates are very high (low feed-meat ratio), because most livestock subsist on grazing, green fodders, and household kitchen wastes—except for commercial poultry raised in cages. This results in very efficient "apparent" conversion of grain to meat, but very inefficient production in the time required to produce meat.[3] There is potential to expand the production of grass- and forage-fed livestock, but most future incremental meat production will require more grain-intensive production.

Consumption projections

There have been numerous efforts to estimate rural and urban income, expenditure, and price elasticities of demand for major food commodities. But the estimates for foodgrains are very unstable and cover the entire inelastic range from 0.0 to 1.0, and those for livestock products range from about 0.8 to over 2.0. Some instability comes from the many years of rationing, when consumption was barely influenced by economic factors. But recent estimates using sophisticated multiple equation models and data for 1993–94, when rationing was suspended, have been equally unstable.

A recent study determined that consumption patterns are influenced by structural as well as economic factors.[4] Residential location (rural, small town, large city) and age are important determinants, and they will become more important as the Chinese population urbanizes and ages. Other studies have determined that income elasticities for food staples (grain) decline at higher income levels—and have projected Chinese income elasticities turning negative for grain by 2010.[5]

Long-term food consumption projections are difficult because of unstable elasticity coefficients and because data on base consumption levels vary. As a result, projections often imply consumption and caloric intake of unrealistic proportions. Projections for indirectly consumed items, such as feed grain, are even more complicated because feed conversion ratios have not been empirically derived and are based on approximations and estimates. Alternative approaches—such as making time-lag and income-lag comparisons with other nearby Asian countries—also are inappropriate given China's extraordinarily high per capita consumption and relatively lower income.

Following a literature review and adjustment of income elasticities to reflect an average annual GDP growth rate of 7.0 percent between 1995 and 2020, the Global Trade Analysis Project (GTAP) model was estimated (using the elasticities in table 2.2).[6] Utilization coefficients, developed from China's input-output tables, allocated grain production to direct consumption, manufactured and processed products, and alternative uses, such as livestock feed.[7] A relatively large proportion of cereal is consumed as manufactured and processed products.

With very large increases in meat consumption, China's feed grain requirements will expand rapidly. For pork, the major meat component, 70 percent is produced under "backyard" conditions using very little grain or manufactured feeds. But unless much of the incremental production comes from more "commercial" operations, the animal numbers will be extraordinarily high. The level of aggregation in the model (as in all general equilibrium models) hides the details of meat consumption (pork, poultry, other), but future consumption growth will likely be greater in more feed-efficient poultry.

The model estimated feed grain needs using a single conversion ratio. But to determine feed grain requirements more accurately, feed needs were estimated separately for poultry, pork, and "other red" meat under the assumption that technology would improve feed conversion by 2020. The total estimated cereal requirements were 608 million tons (table 2.3).

The requirement for food grain (direct and indirect) will be about 368 million tons, for feed grains 206 million tons, and for other uses 34 million tons. Some coarse grains will continue to be used as a food grain, and some fine grain will be used as feed. Wheat bran, as a flour milling by-product, will continue to go into feed. About 12 percent of rice production is now used to feed livestock, because of the low price of hybrid rice and the constraints on transporting coarse grains into rice areas. The model suggests that rice used in livestock feed will increase to 22 percent of production in 2020, but better market integration would improve food and feed grain allocations.

Two other studies also looked at China's foodgrain requirements. The International Food Policy Research Institute (IFPRI) study explicitly addressed the cereal requirements of only food and feed.[8] If "other" uses were added, the total requirements would be 587 million tons, similar to the World Bank estimates. The FAO study estimated requirements for 2030 and allocated "200 kilograms per capita for all other uses," which, if intended to include nonfood and nonfeed uses, is about 6 percent below the other two estimates.[9] The different models use quite different methodologies, yet all reach the conclusion that about 600 million tons of cereals (687 million tons of unmilled trade grain) will be required in 2020 (table 2.4).

TABLE 2.2
Estimated direct food consumption, 2020

Food	Income elasticity	Per capita consumption (kilograms)	Total consumption (million tons)
Rice	−0.05	66.5	94.6
Wheat	0.07	51.5	73.9
Coarse grains	−0.18	23.1	31.9
Meat	0.62	51.3	73.6

Source: World Bank data and staff estimates.

TABLE 2.3
Estimated cereal requirements for 2020
(million tons)

Grain use	Rice[a]	Wheat	Coarse grain	Total
Cereals for food	94.6	73.9	31.9	200.3
Manufactured products	56.3	68.6	43.1	168.0
Feed grains	46.3	21.6	138.2	206.1
Seed requirements	1.1	3.5	1.6	6.2
Postharvest loss[b]	10.4	7.2	9.7	27.3
Total	208.6	174.8	224.5	607.9

a. Total paddy equivalent is 297 million tons.
b. Postharvest losses are assumed to be 5 percent of production.
Source: World Bank data and staff estimates.

Clarifying assumptions

Estimates of total cereal requirements are sensitive to several factors. Changing the annual average growth rate to 7.5 or to 6.5 percent would increase or decrease total

TABLE 2.4
Alternative estimates of cereal requirements
(million tons)

Grain use	In 2020: This study	In 2020: IFPRI	In 2030 FAO
Food	368.0	298.4	263.3
Feed	206.0	232.0	ne
Other	34.0	ne	292.6
Total	608.0	530.4	555.9

ne Not estimated.
Source: World Bank staff estimates; for IFPRI, Rosegrant, Agcaoili-Sombilla, Perez (1995); for FAO, Alexandratos (1997).

cereal needs by 17.5 million tons, with most of the change occurring in coarse grain requirements. But China's large population means that small changes in per capita consumption would result in large changes in total estimates. Small changes in income elasticities or price elasticities would also result in significant changes in total cereal requirements. Similarly, small changes in feed conversion ratios produce large changes in total estimates. So any estimate should be carefully examined to ensure that the assumptions are understood and acceptable.

Notes

1. Garnaut and Ma (1992).
2. Based on the *World Bank Atlas* method. Malaysian per capita GNP would be 230 percent greater if based on purchasing power parity estimates.
3. Pigs produced under "backyard" conditions use very small amounts of grain but require 12–14 months to reach marketable weight; "specialized households" typically market their animals in 6–7 months.
4. Huang and Bouis (1996).
5. Chern (1997); Huang, Rosegrant, and Rozelle (1997).
6. The Global Trade Analysis Project (GTAP) model is a global general equilibrium model maintained at Purdue University by a consortium of research and policy institutions including the World Bank, World Trade Organization, European Commission, OECD, and numerous bilateral agencies. The model and its underlying database, documented in Hertel (1997), are widely used for analysis of agricultural and general trade policy worldwide.
7. China State Statistical Bureau, "Input-Output Table of China" for 1987 and 1992.
8. Rosegrant, Agcauili-Sombilla, and Perez (1995).
9. Alexandratos (1997).

chapter three

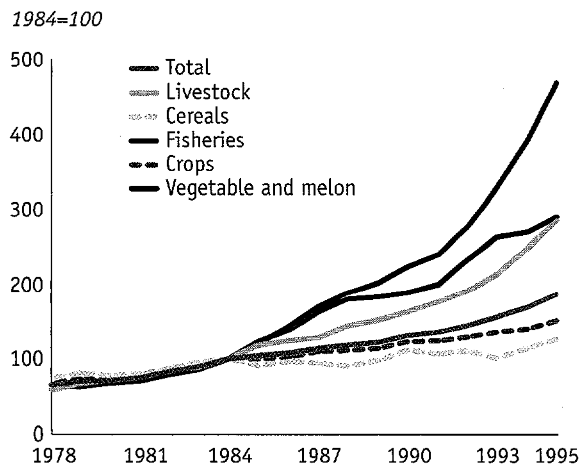
Past Growth, Coming Constraints, and Solutions

Agricultural growth since 1978 can be divided into the Household Responsibility System implementation period (1978–85) and the post-implementation period (1985–95). In the first period agricultural growth averaged 7.4 percent, and total factor productivity[1] growth was 6.6 percent.[2] In the second period growth declined to 5.8 percent, created primarily by additional inputs and investments, and total factor productivity growth declined to 1.1 percent (1985–89). These slowdowns in both total factor productivity and agricultural growth raise concern about the future growth of agriculture and food production.

The various components of agriculture and food production grew at very dissimilar rates, particularly after 1985. Cereal production increased the least, reflecting its low profitability. Nonstaple foods, livestock, fisheries, and vegetables and melons grew at 9 percent or more after 1985 (figure 3.1).

FIGURE 3.1

Index of gross output of agricultural components, 1978–95



Source: China Statistical Yearbook various years.

Accounting for past growth

Various studies have identified investments, primarily public investments, and institutional innovations as contributing to rapid growth. One study concluded that the institutional reform reintroducing the Household Responsibility System was the major element influencing agricultural growth in the early 1980s.[3] The fact that growth rates declined after 1984, when 99 percent of all villages had adopted the Household Responsibility System mode of production, supports this view. To analyze the contribution and impact of factors on crop production growth, a dynamic multisector output response model was specified to evaluate growth during the reform period (table 3.1).

Growth was analyzed separately for southern and northern China using different crops to account for the different cropping patterns and agroclimatic environment. Variables in the analysis were the Household Responsibility System (institutional reform), investments in research and water control infrastructure, input-output price ratios, land and labor prices, and environmental factors. Land use and markets and agricultural extension were excluded because of the lack of change in the land factors and the inability to quantify changes in extension. Their contribution to growth is undetermined and by default is in the residual.

The analyses confirmed that the Household Responsibility System was important, contributing more than 2 percentage points to agricultural growth in southern China during 1978–84. But its impact in northern China was mixed, contributing 3.8 percentage points annually to the growth of wheat production but nothing to the growth of corn production. Other important contributors to growth were investments in agricultural research, the engine of agricultural growth during the reform period. Irrigation infrastructure investment, another important contributor to agricultural growth, may have added more than the coefficients indicate because many of the investments were for infrastructure rehabilitation and compensation (to compensate for irrigated land lost to urban and industrial growth) rather than for capacity expansion.

TABLE 3.1

Contribution to crop production growth

	Southern China				Northern China			
	1978–84			1984–95	1978–84			1984–95
Contributor	Rice	Other grain	Cash crops	Rice	Wheat	Corn	Wheat	Corn
Research stock	1.61	5.03	8.51	1.65	3.30	5.84	3.43	6.07
Irrigation stock	0.13	0.22	0.00	0.39	0.43	0.46	0.47	0.50
Institutional reform (Household Responsibility System)	2.10	2.71	2.23	0.00	3.86	0.00	0.00	0.00
Input-output prices	0.44	1.18	0.99	−0.11	0.86	1.94	−0.75	−1.14
Land prices	−0.03	0.00	−9.14	−0.01	−0.04	1.83	−0.01	0.40
Labor prices	−0.96	−2.95	1.29	−0.21	−1.30	−5.90	−0.08	−0.36
Environmental factors								
Disaster	0.06	0.20	0.02	−0.07	0.30	0.36	−0.02	−0.03
Erosion-salinization	0.00	−0.37	−0.86	0.00	0.01	0.13	−0.02	−0.35
Residual	1.20	1.35	11.55	−1.28	0.21	−1.17	−0.09	−0.19
Growth rate	4.54	7.37	14.59	0.36	7.63	3.48	2.12	4.89

Source: World Bank staff estimates.

Agricultural research

By creating new technologies and crop varieties and improving agronomic practices, China's research system has raised total factor productivity in agriculture and expanded crop production in the face of declining output-input price ratios. The growth accounting analysis was consistent with the conclusions of other scholars who have found that growth in Chinese agricultural productivity was overwhelmingly attributable to research investments.[4] The high social returns to agricultural research have been well documented for many countries.[5] Government investment in research and development resulted in 20 percent agricultural productivity growth between 1965 and 1994.[6] Other work has estimated that the internal rate of return to agricultural research over the same period averaged 94.4 percent.[7] This high return means that China is underinvesting in its agricultural research, a public good that should be fully funded from the public treasury.

Research in any given year builds on past research and adds to the foundation for future research. Research investments accumulate and last for several years before fully depreciating. Thus, research *stock* is more important than investments in any particular year (except for continuity of research projects).

Areas for concern

Although China's agriculture has been well served by research, three issues create concern for the future. The primary issue is the *budgetary allocation* for agricultural research. National agricultural research budgets have quadrupled in real terms over the past three decades, and the number of research scientists employed has increased sixfold.[8] But these numbers are deceptive. Funding per scientist has declined, and funds per scientist influence output (new varieties) more than total budgets. Research costs have generally increased more rapidly than inflation—genetic research is turning to more costly biotechnology. And research has expanded to incorporate pest resistance and drought tolerance along with the former focus on higher yields and shorter seasons. One study concluded that funds actually spent on rice research per active scientist-year declined during the 1990s.[9]

Another budget issue is the inefficient use of funds. Research could be made more cost effective by defining research priorities better. Given the increasing demand for feed grains, research to develop and adapt corn varieties for the traditional rice areas should have a high priority. In addition, livestock research receives a disproportionately small share of the budgetary resources. Restructuring the research system, basing it on agroecological zones rather than administrative zones, would also improve efficiency—because crop research is often duplicated by research institutes at different levels in different regions.

Equally important is the decline in agricultural research intensity (table 3.2). Between 1975–79 and 1990–94 research spending slipped from 0.5 percent of agricultural GDP to 0.4 percent (the coefficient excludes research funded from provincial budgets). This ratio is slightly below the average of other developing countries but only one-fourth of the investment ratio of industrial economies. Without consensus on appropriate agricultural research intensity, it is recommended that China reverse the declining trend and raise the agricultural research intensity above the developing country average.

The de facto decline in the research budget has been exacerbated by the research *commercialization* of the past decade. Research institutes have been encouraged to commercialize their activities and earn a portion of their income through technology sales. Ideally, the institutes would license the technology to manufacturers and commercial entities, but weak protection for intellectual property rights made this less attractive than the commercialization option. Commercialization thus evolved into unrelated activities with higher capturable returns, including manufacturing, restaurants and

TABLE 3.2

Central government investments in agricultural research

Period	Number of research scientists	Agricultural research intensity[a]	Average annual expenditures (1990 yuan): Total (millions)	Per scientist
1965–69	10,166	0.33	464	46,001
1970–74	10,618	0.41	720	68,518
1975–79	19,319	0.49	1,022	52,729
1980–84	33,111	0.44	1,404	42,482
1985–89	50,330	0.40	1,763	35,336
1990–94	61,835	0.39	2,063	33,276

a. Agricultural research intensity is the ratio of agricultural research expenditures to agricultural gross domestic product.
Source: World Bank 1997b (annex table A.7.1).

hotels, and commercial trade. Diverting researchers from their primary task seriously detracts from the institutes' research objectives, especially since only about 15 percent of the commercial revenues are allocated to the institutes' research budgets.[10]

The third issue relates to the *competitive grants program,* initiated in 1982 by the Chinese Academy of Sciences, which allocates funds directly to research scientists. Conceptually, competitive grants are an efficient method of allocating research funds, but they may favor established scientists and institutes and make it difficult for younger, better trained scientists to participate. The competitive funding has shifted resources to national institutes at the expense of prefectural institutes. Whether this is efficient remains to be determined—prefectural institutes introduced more than half of the new rice cultivars between 1990 and 1994.

Productivity and output of research

Research has shown that the number of new rice cultivars developed, released, and commercially used in the first half of the 1990s was similar to that of the first half of the 1980s but 25 percent below the output in the second half of the 1980s.[11] Note, however, that yields continued to increase despite the reduction in new cultivar releases. Are the productivity and output of research declining? The evidence is insufficient to conclude that they are, but more consideration must be accorded to the possible weakening of the agricultural research system. And it could signal the inadequacy of technology transfer. Research staff state that only 30 percent of the technology developed is regularly applied in farmers' fields and that the balance remains on the shelf, even though new-variety adoption rates are about 80 percent. This might, however, simply reflect high-risk or financially unattractive technology.

Although Chinese counterpart agencies have access to technology generated by the institutions affiliated with Consultative Group on International Agricultural Research, China benefits little from agricultural technology developed by private international corporations such as transnational seed companies.[12] Greater internationalization of research and technology through increased cooperation with international public and private institutions would be mutually beneficial.

The overall conclusions, given the overwhelming contribution of research to agricultural growth, are that real investments in research must be better managed to ensure that efficiency and long-term food security objectives are met. And research funding must increase enough to maintain annual total factor productivity growth at 1.0 percent in grains—otherwise, declining production growth will necessitate more imports.

Fertilizer

The widespread use of chemical fertilizers has been a major factor in the remarkable increase in grain and food production. Domestic production, using both indigenous local technologies and modern international technologies, provides 70–75 percent of the fertilizer nutrient supply. Fertilizer use has quadrupled since 1978, spurred by fertilizer-responsive crop varieties. Fertilizer used in 1995 was valued at 125 billion yuan, making it the major cash input in crop production.

Worrisome, however, is the apparent declining effectiveness of incremental fertilizer application. This has led some analysts to conclude that the potential for further yield increases, using existing cultivars, is limited.[13] The Chinese Academy of Agricultural Sciences has identified four causes of fertilizer's declining effectiveness: unbalanced and underapplication of nutrients, especially underuse of potash; poor quality of fertilizers; poor application methods; and poor distribution.

Unbalanced supply and use of nutrients

Even though the importance of proper nutrient balance is well known, and generalized ratios of 100:50:25 (nitrogen, phosphate, potash) have been recommended for several years, China's application ratios in 1995 were 100:47:16. (Korea applies a 100:120:80 ratio, and Japan 100:40:40.) This study analyzed macro-nutrient balances on the basis of a detailed investigation of the input and uptake for the most important crop and livestock products.

The investigation found that in 1995 nearly 3 million tons of applied nitrogen and just over 2 million tons of applied phosphates were not used by crops and livestock, but potash removal was 6.7 million tons greater than the amount applied (table 3.3). The excess nitrogen and phosphate, valued at 18 billion yuan, was

TABLE 3.3
National nutrient balances, 1995
(million tons)

Fertilizer	Nutrient input[a]	Nutrient (crop and animal)	Assessed losses	Balance
Nitrogen	32.5	19.5	10.1	2.9
Phosphate	12.5	6.8	3.5	2.1
Potash	12.6	17.5	1.9	-6.7

a. Includes chemical fertilizers, crop residues, animal feeds, organic wastes, atmospheric deposition, and nitrogen fixation.
Source: World Bank staff estimates.

TABLE 3.4
Average yield response to potash in balanced fertilizer trials
(kilograms per hectare)

Crop	Potash applied[a]	Yield with potash	Yield without potash	Increment	Average yield[b] response
Rice	98	6,038	7,020	982	10
Wheat	98	2,790	3,900	1,110	11
Corn	113	5,048	6,570	1,522	13
Tomato	165	23,318	30,773	7,455	45
Broad beans	120	2,145	3,233	1,088	9
Watermelon	150	31,290	38,430	7,140	47
Citrus	n.a.	40,148	53,783	13,635	n.a.
Pineapple	375	22,530	28,590	6,060	16

n.a. Not available.
a. Nitrogen and phosphate fertilizers were balanced.
b. Output per kilogram of potash.
Source: Stauffer and Denton 1995.

essentially wasted—possibly contributing to environmental pollution. The underapplication of potash diminished the efficiency of nitrogen and phosphate uptake, and crop production was lower than it would have been with balanced fertilizer application. This analysis is consistent with a recent study of nutrient input and output on farms by the China National Rice Research Institute.

In the short run nutrients are applied only to the extent that there is an economic yield response since some nutrient uptake is provided by soil nutrient reserves. But for long-run sustainability, crop and animal nutrient uptake must be replaced by natural processes (atmospheric deposition, biological nitrogen fixation) or by fertilizer.

Field trials undertaken by Chinese agricultural research entities indicate how yields would respond to balanced potash, nitrogen, and phosphate application (table 3.4). The potential increases in crop productivity from a balanced application of fertilizers range from 16 to 50 percent, even more than the estimates of soil fertility and fertilizer researchers, who state that properly balanced fertilizer application would increase yields by 12 to 15 percent. It is not clear why more potash is not used in China despite solid evidence of the benefits. One reason could be that fertilizer use in China has evolved on the basis of local supplies. Nitrogen is the most abundant locally sourced fertilizer and is used most. Local phosphates have become available on a large scale only in the last decade, and phosphate use has increased in line with domestic production. Very little potash is available locally, and it is costly to produce.

Fertilizer supply and underapplication

The average application rate of plant nutrients is officially given at about 240 kilograms per hectare. But recent satellite imagery indicates that the cultivated land base is about 40 percent greater than land statistics indicate and there is double counting of about 10 percent of the single-nutrient fertilizers blended into compound fertilizers. Correcting for these statistical anomalies reduces the application rate to a very modest 155 kilograms per hectare. China's average fertilizer application rate is therefore below the East Asian developing country average and far below that in Japan and the Republic of Korea, where yields are higher. This low application rate may result from the limited supply.

Planning guidelines call for nitrogen self-sufficiency and 75 percent self-sufficiency in phosphates by 2000, with the increased production to come from large plants that would cost more than $5 billion. This 2000 objective will not be met. The manufacturing plants now under construction that will be completed by 2000 will have a capacity of about 2.1 million tons of nitrogen equivalent. But during the late 1990s nitrogen consumption will grow by 3 million tons, increasing the deficit to about 5 million tons by 2000—if ammonium bicarbonate production remains constant. To replace imports with domestic production would require twelve or thirteen additional plants—with an investment of about $4.4 billion, based on cost estimates of $350 million for a 400,000-ton nitrogen plant. Whether such an investment would be efficient is difficult to judge because the international price of urea is volatile. But if domestic energy costs can be maintained below $2 per million British thermal units, domestic manufacture should be cheaper than importing.

Fertilizer imports are centrally controlled and have averaged 8.6 million tons (nutrient content) annually over the past decade. Urea has been the major import, followed by potash and compounds. SINOCHEM, a Ministry of Foreign Trade and Economic Cooperation company, has the exclusive right to import fertilizer, leveraging its position to obtain very favorable prices. It is inflexible, however, and has not responded to demand changes. China must be prepared to import large quantities of potash because local supplies can meet only a small fraction of requirements.

Poor quality of fertilizers

About half of China's supply of nitrogen and phosphate consists of low-grade ammonium bicarbonate, single superphosphate, and fused magnesium calcium phosphate, produced in small factories. Using ammonium bicarbonate as a nitrogen nutrient source is unique to China. Its manufacture involves a relatively simple technology using widely distributed anthracite coal deposits (or coke) as feedstock. This permitted China to build up production capacity and expand nitrogen fertilizer application. But its manufacture is relatively energy inefficient (mitigated by the abundance of anthracite) and highly pollution prone, and it decomposes in storage.

Similarly, phosphate fertilizer production remains primarily low-analysis single superphosphate, which can be manufactured from widely distributed low-grade rock using simple, low-cost technology. Single superphosphate provides traces of the minor element sulfur, in which Chinese soils are deficient, and would have to be applied separately if triple superphosphate were widely used. These low-grade materials have low nutrient content (less than 20 percent), which makes them costly to transport and handle, and have poor agronomic efficacy.

The small-scale production of low-grade nitrogen and phosphates using local technologies is a remarkable feat, but it has left China with inefficient, polluting factories and an antiquated industry structure. As application volumes increase, it will become more important to improve production and transport efficiency by shifting to higher-analysis fertilizers.

New factories using modern technology and producing high-analysis, high-quality products are under construction, and others are planned. But they will meet only incremental needs, and they will not immediately replace the low-grade fertilizers. New incentive structures and special efforts are needed to accelerate the construction of new, modern factories, which require large investments and gestation periods of a decade or more.

Poor methods of applying fertilizer

Because fertilizer is broadcast, it is estimated that half the nitrogen applied to irrigated fields is lost to evaporation. Applying the fertilizer directly to the root zone by using fertilizer drills or slow-release fertilizer tablets would reduce this problem. The nitrogen in ammonium bicarbonate is particularly volatile, even evaporating in storage. Because the fertilizer cannot be stored for long periods, ammonium bicarbonate plants often cannot be operated in the fallow seasons when fertilizer is not needed, and that increases costs. Evaporation is not a problem with the low-grade phosphate fertilizers, but not all of the phosphate is water soluble and thus is not immediately available for plant uptake.

Land

China's cultivated land per capita is low, but land is not a limiting food security constraint given the potential for higher yields under balanced fertilizer application, for expanding agricultural land through land reclamation, and for long-term investments in land if farmer incentives are improved.

Official sources list China's cultivated land at 95 million hectares and sown areas at 145 million hectares. However, satellite imagery indicates cultivated area of some 132 million hectares. If crops are distributed proportionally on the more than 37 million hectares of cultivated land not in the official estimates, individual crop yields and fertilizer application rates are 40 percent lower than officially reported.

International yield comparisons are easier to interpret for rice yields than for other crops because rice is almost always irrigated, while other crops are grown under both rain-fed and irrigated conditions. Under the revised estimate of cultivated land, rice yields remain higher and wheat and corn yields similar to the Asian average. Cereal yields are well below those of many major producing countries and less than half those of the top-ranked country. This does not imply that average Chinese yields can be increased to those of other countries (say, rice yields equal to those in Australia) because climatic conditions are different. But it does show the substantial potential for improvement, particularly for corn (table 3.5).

The land base is steadily diminished by residential and industrial encroachment and infrastructure construction. Since 1988 construction has removed 190,000 hectares of agricultural land from cultivation annually, about a third of the annual decrease. (Some recent studies suggest the actual cultivated area may be substantially greater.) These losses have been concentrated in the Shandong and southeastern coastal provinces, where high multiple cropping compounds the land loss. Land reclamation, averaging 245,000 hectares annually, has partially mitigated those losses (though newly reclaimed land is less productive than that lost to capital construction). Some cultivated land is lost by transferring it to alternative agricultural uses such as pastures, forests, and fish ponds. Other fluctuations come from marginal land that is cultivated or lies fallow, depending on prices and profits.

An estimated 13.5 million hectares of barren land, 24.0 million hectares of tidal land, and 2.0 million hectares of wastelands are potentially reclaimable, although infrastructure and farm buildings would reduce the cultivable area by 25–30 percent.[14] These areas are widely distributed around the country, but with almost 50 percent in Xinjiang and Heilongjiang, where water shortages would constrain reclamation. And some of these lands are in remote areas or are low in fertility—but could still be productive as pasture or forest. About 25 percent of the land lies within, or south of, the Yangtze River Basin and would be more amenable to irrigation, especially the "red soil" areas. One-third of the potentially reclaimable tidal lands are in the coastal provinces on the Bohai Gulf (Liaoning, Tianjin, Hebei, and Shandong). The cost of reclaiming these lands varies from a low of 15,000 yuan per hectare for barren land to 150,000 yuan for tidal land.

Land productivity is reduced by floods, erosion, water logging, and salinization and alkalinization, but the areas vulnerable to those conditions are increasingly being controlled and improved. The cropping index ranges from less than 100 in some northeastern and northwestern provinces to more than 250 in Hubei. Short frost-free periods limit the potential for increasing the index in the northernmost and high-altitude provinces, except for greenhouse production of vegetables, and water shortages limit multiple cropping in other northern locales. But improved water control, short-season varieties, and appropriate production incentives will stimulate additional multiple cropping in the southern and middle provinces.

TABLE 3.5

International yield comparisons, 1991–94 average
(kilograms per hectare)

Country or group	Rice	Wheat	Corn
China (official estimates)	5,793	3,317	4,777
China (revised estimates)	4,138	2,369	3,412
Asian countries	3,668	2,500	3,462
Developing countries	3,514	2,424	2,670
Industrial countries	5,671	2,556	6,249
Argentina	4,471	2,158	4,289
Australia	8,284	1,581	4,853
Egypt	7,566	5,093	6,116
France	5,035	6,559	7,775
Italy	6,558	3,497	8,236
Korea, Rep. of	6,060	3,007	4,798
Thailand	2,185	—	2,871
United States	6,421	2,510	7,522

— Not available.
Source: UN Food and Agriculture Organization database.

Water resources

Water scarcity is China's most limiting agricultural production resource, particularly in northern corn- and wheat-growing regions. Investments in improved water control and delivery systems would conserve water and modestly improve yields.

Irrigation efficiency

Only about 30 percent of the water diverted into irrigation canals is actually delivered to crop root zones, due to delivery inefficiencies and inefficient on-farm water use. Delivery improvement will require lining the canals and other investments (pipe and hose systems), and on-farm efficiency could be improved with appropriate water pricing. Efficiency gains in delivery and application must be pursued, but achievable gains are limited. Even with improved efficiency, productivity growth will require incremental supplies.

Incremental supplies

Annual average water runoff in China is considerably below the world average, and only about a third of the runoff is exploitable. Actual water exploitation was only 60 percent of the potentially exploitable supply in 1993. Capturing more will require large investments in storage, diversion works, recycling, pumping, and conveyance systems.

Major increases in the supply of exploitable water to northern China must await the completion of one or more of the three components of the south-north transfer scheme from the Yangtze River. Prefeasibility studies on the eastern and middle of the planned routes concluded that 20 to 25 billion cubic meters a year could be transferred to the arid north with investments of $10 to $15 billion.

Wastewater is discharged into waterways for downstream use, but much of it is untreated. The health and environmental consequences are unknown. Considering the large anticipated water allocations to municipal and industrial users over the coming decades, investments in wastewater treatment and recapture for irrigation are necessary to prevent outbreaks of waterborne diseases, ensure uncontaminated food supplies, and support food production. Also, mixing irrigation drainage water with fresh water for reuse can expand the available water supply by as much as 25 percent.

Water consumption

Industries, municipalities, rural residents, and irrigated agriculture are the major users of captured water. Water for irrigation is a residual, determined by alternative uses that are expected to grow rapidly during the next two decades, especially municipal and industrial uses. Increases in industrial water requirements are closely linked to industrial growth, projected at a sustained 6 percent a year through 2020. Municipal water consumption is determined by the urban population size (although it is rationed in some northern cities), which is projected to grow 4 percent a year in the 1990s and 3 percent in the 2000s. Water demand by rural households is projected to stabilize, because small per capita increases are balanced by a shrinking population.

Requirements for irrigation water depend on the effectively irrigated area, efficiency of the delivery systems, and cropping practices. But as a residual user, irrigation requirements may not be met. For food security it is more efficient to fully irrigate as much as possible with the water available and to idle (or cultivate as dryland) the balance. Since this is unacceptable on equity grounds, water deficits will instead be shared, with consequent reductions in production.

Water conservation investments

Government investments in water conservation have fluctuated over the past four decades but have consistently claimed about 70 percent of agricultural investments. Real investments were relatively low during the 1980s, reflected in the small marginal increase in irrigated area. Both investments and irrigated area increased sharply in the 1990s, with irrigation investments trebling (in 1990 yuan) and irrigated area expanding by 10 percent between 1989 and 1995. The marginal cost of this expansion was 10,000 yuan per hectare, representing very efficient investments. Investment should emphasize water-saving technology.

The marginal cost of further irrigation expansion will be considerable because the less costly projects have already been completed and water will be increasingly diverted from agricultural to nonagricultural uses, making it costly to maintain the irrigated area. Cost estimates for increasing water supplies through treating and recycling industrial water and for improving distribution systems are unavailable.

Infrastructure

Most grain continues to be consumed on the farm or in the village where it is produced. Only a third of the cereal produced is marketed outside the village of production. But with increasing urbanization and use of cereals for livestock feed, the marketed surplus will increase rapidly. However, lack of transportation and supporting infrastructure are serious constraints to food marketing and distribution. Especially deficient are facilities for bulk grain transportation, intermodal transfers, handling, and transit storage. Refrigerated transport and storage for perishable products are also lacking. The inability to rapidly move large quantities of grain creates fragmented markets and impedes the development of rational grain markets.

Bulk grain logistical systems

Bulk logistical systems create benefits that would be unavailable if the system components were introduced individually. To market grain more efficiently and rapidly China needs more dedicated bulk-handling systems in high-density grain corridors. Because of their high cost such systems are justifiable only on high-volume corridors. China's inadequate number of deep-water ports, dedicated grain berths, and port-handling facilities make external grain flows unnecessarily costly. Lack of domestic bulk transport facilities makes transfers between the interior and the coast similarly difficult. Bulk intermodal transfers are limited to a bulk grain shuttle system that transfers imported wheat from Tianjin to Beijing and low-volume transfers from Dalian to inland northeastern cities.[15]

Ports. Fourteen major ports handle nearly all of China's internationally traded grain. But only Dalian, Lianyungang, Qinhuangdao, Shanghai, Zhanjiang, and Tianjin have specialized grain-handling berths. Others are under construction at Dalian, Fengcheng, and some Yangtze River ports. High-capacity bulk unloading equipment is available at some major import terminals, but bulk loading facilities are generally lacking. For most ports bulk unloading consists of low-capacity grab cranes, conveyor hoppers, and often improvised portable conveying equipment that cannot be operated in inclement weather. The lack of dedicated all-weather, high-capacity, off-loading equipment increases port transfer costs. Discharge and demurrage costs range from $4,000 to $12,000 a day per vessel (depending on the size and age of the vessel). Daily loading charges are generally double the discharge cost.

There are 394 coastal berths classified as "deep-water berths" capable of handling vessels of 10,000 deadweight tons (dwt), but no data are available on the number of berths capable of accommodating larger vessels. Most grain vessels calling at Chinese ports are 45,000 dwt to 50,000 dwt. There are no grain berths capable of handling 80,000 dwt ("Panamex") vessels. Because transocean shipment is more costly on smaller vessels, ocean freight costs on China-destined grain are higher than for countries receiving the larger vessels.[16]

Port facilities have been adequate if not efficient. Importing grain on smaller vessels and slow off-loading at poorly equipped ports cost an estimated $10 extra per ton. If grain imports treble in the next two decades, this could amount to as much as $400 million extra per year. Looked at another way, potential savings of $400 million could be achieved if adequate investments are made in deep-water berths and port-handling equipment.

To efficiently accommodate future grain flows, China must add a new 4–5 million ton capacity bulk deep-water grain berth every two years over the next two decades. Berth and bulk-handling investment costs would be roughly $60 to $85 million per berth, depending on existing ancillary facilities.

Grain flows through inland ports have remained remarkably constant during the 1990s, averaging 6.5 million tons a year of bagged grain, a slow and costly pace. Although neglected in China, inland waterways are intensively used in other parts of the world as a low-cost transport mode for bulk grain. One reason for the neglect is the administratively determined rail tariffs which, unlike in other countries, are below barge tariff rates. Market-determined tariff rates for all transport modes would increase the demand for bulk barge transport along the major inland waterways.

Rail transport. Rail movements of grain rose from 45 million tons in 1985 to 67 million tons in 1995, thanks to improved efficiency. Further efficiency gains will be difficult, however, as rail wagon utilization is now 98 percent and load factors for grain have reached 99 percent of wagon capacity. Some modest efficiency increases will be possible through increased train speeds and shipping distances. Ninety-nine percent of the grain is transported in bags; only 1 percent is transported on the Tianjin-Beijing bulk shuttle.

China has made very large investments to expand railway capacity, and more are planned, but limited transit capacity seriously constrains feed grain shipments from northeast China to southern destinations. Grain-specific investments are difficult to justify because grain is only 4 percent of rail freight, although grain requirements of bulk users (food millers and manufacturers, feed millers, and industrial manufacturers) will increase. Special-purpose bulk wagons would boost efficiency by increasing wagon utilization and turnover per wagon. Bulk wagons would reduce loading and unloading time to minutes from the one to two days now allowed by the Ministry of Railways.

Bulk rail wagons should be used only on high-volume rail corridors, preferably with backhaul opportunities, with bulk loading and unloading facilities at railheads. Individual bulk hopper wagons with annual turnover capability of about 4 million tons per kilometer annually (based on a 1,400 kilometer average distance of grain shipments) cost about $50,000 each. A $625 million investment in 12,500 bulk wagons would handle half of the grain traffic, but ancillary loading and unloading facilities would require further investments to reap the full benefits of bulk transport.

Storage. Grain storage requirements increase as grain production and domestic trade expand, but much of the storage capacity is constructed on-farm. The state adds about 1.7 million tons of storage space annually, mainly long-term storage for reserves. Virtually all of these additions are flat warehouse storage, which does not lend itself to rapid movements in and out. China could reduce government storage by relying on nonstate enterprises to market and distribute grain if more flexibility were permitted for variations in price by season and region.

High-throughput transit storage is crucial to efficient intermodal interfacing in a bulk grain logistical system. Transit storage requirements at intermodal transfer points are highly site-specific and must be carefully calculated to avoid unused storage. Transport arrivals and departures must be well timed to ensure high throughput.

Bulk fertilizer logistical systems

With most food and agricultural production on small farms, bulk handling of fertilizer between manufacturer and farmer would be impractical, though it could be efficient for some state farms. And as larger domestic fertilizer manufacturing plants are constructed, bulk delivery to bagging centers in agriculture-intensive areas should be considered for some of the output, to avoid repetitive and costly bag handling.

Policies and institutions

Most grain policies are control oriented, urban biased, focused on the short term, and impede long-term food security. Managing and supporting the grain sector is complex because it directly involves five ministries and several agencies. The nongrain foods—fruit, vegetable, and livestock products—are produced and marketed in a basically free market, but government intervention remains the norm for cereals. During the late 1980s and early 1990s the government gradually liberalized grain policy and reformed grain institutions, primarily through liberalized retailing, but rapid price increases in late 1993 led to retrenchment in 1994. Subsequent reform has been modest, focused on decentralization. The major objectives of grain policy are to:

- Maintain 95 percent grain self-sufficiency as stated in the government's White Paper by the Information Office of the State Council.[17]
- Increase control of production, pricing, and marketing—government quota procurement of 50 million tons plus 40 million tons of additional procurement to control 70–80 percent of the marketed grain.
- Continue controlling stocks and international trade.

Governors Responsibility System and the pricing-marketing framework

In 1995 the central government delegated responsibility for balancing local supply and demand and for some pricing and marketing of grain (including financial responsibility) to the provinces. Market transactions between government grain enterprises in surplus and deficit provinces replaced centrally planned interprovincial grain transfers. Government grain enterprises from deficit areas are forbidden to procure grain in the countryside in grain surplus areas, and they must buy from wholesale markets at the county level or above. Surplus-producing provinces must maintain a three-month supply of grain stocks—and deficit provinces a six-month supply. Provinces are free to subsidize farmers' inputs and consumers' purchases as their revenues allow. Private traders cannot procure grain in the countryside until state grain quotas have been filled.

The state retained the grain quota (for below-market-price grain, which must be delivered to grain bureaus), national stock responsibility, and the international grain trade monopoly. The effect of the Governors Responsibility System policy was to decentralize responsibilities, replacing the nationwide policy with a multitude of provincial policies. But the policy content changed only marginally. Decentralization, by itself, had little influence on the record grain production of 1995 and 1996, attributable instead to higher prices and good weather.

Quota procurement and farm income

In 1995, 142 million tons of grain, 30 percent of total production, were marketed outside the village of production. Government grain enterprises procured 65 percent of this quantity—purchasing 46.2 million tons of quota grain and an additional 46.3 million at negotiated prices (table 3.6). Quota grain prices averaged 60 percent of the free market price; negotiated prices 90 percent. These below-market prices imposed a total implicit tax of 40.7 billion yuan on grain producers. Recent grain price and production increases show that farmers respond to price; conversely, artificially low average prices depress production and marketed surpluses and make food security more difficult. Because incomes of grain farmers are typically below those of aquatic, livestock, fruit, and vegetable producers, the tax is discriminatory as well.

The government proposes to procure 1997 grain quotas at market-determined prices and to discontinue consumption subsidies through the grain enterprises. It will retain procurement quotas to control grain stocks. Unifying prices at the market level will improve farmer incomes, but the purchase price will remain state-determined, albeit with competition between various government grain enterprises. Nongovernment grain enterprises will participate in the market only after the state satisfies its procurement needs.

State grain enterprises

The grain bureaus have two conflicting roles: to perform regulatory and policy functions and to operate commercially profitable enterprises. This two-track system allows enterprises to mix staff, activities, grain stocks, and financial accounts. Quota grain is sold as higher-priced negotiated grain. Reserve grain is used for commercial stocks. Consolidated accounts make it easy to reallocate commercial losses to policy losses and then to claim government reimbursement.

Although not a pure monopsony the grain bureaus procure grain at below-market (and largely government-determined) prices before competitive procurement is permitted. They have little incentive to be efficient because their losses are reimbursed, and they have minimal competition for raw materials and only modest competition in marketing (grain bureaus procure 70–80 percent of marketed surplus). Their reform has focused primarily on retail marketing.

Most consumers now purchase the major share of their grain from the private sector, but private retailers purchase most of their stocks from grain bureau enterprises. An element of competition was formerly generated by grain bureaus from various locales competing to procure farmers' surpluses. But this competition has been reduced by the Governor's Responsibility System and accompanying regulations.

Pricing policy, combined with the grain bureaus' inefficiency, is costly. IOU procurement is prohibited, but there are reports of delayed or closed procurement due to lack of funds or storage space.[18] Grain bureau net losses continue to accumulate, rising to 19.7 billion yuan in 1996, and government consumption subsidies for "grain and edible oil" have averaged 20 billion yuan a year over the past five years.[19]

Grain policy and enterprise inefficiency cost 80 billion yuan a year (implicit farmer taxes, losses, and consumption subsidies), so reform is imperative. Full market competition must replace the near monopsony that the grain bureaus now enjoy. To achieve and main-

TABLE 3.6
Government grain procurement and value, 1995

	State procurement (million tons)		Production	Price (yuan per ton)			Implicit tax
	Quota	Negotiated	(million tons)	Quota	Negotiated	Market	(billion yuan)
Rice[a]	18.4	10.3	185.2	1,107.5	1,729.0	1,897.5	16.3
Wheat	17.1	14.1	102.2	1,080.0	1,528.0	1,688.0	12.7
Corn	9.3	15.0	112.0	855.0	1,385.0	1,580.0	9.7
Soybeans	1.0	4.2	13.5	1,814.0	2,422.0	2,711.0	2.1
Other	0.4	2.7	56.7	na	na	na	na
Total	46.2	46.3	469.6	na	na	na	40.7

na Not applicable
a. Average for indica and japonica (unmilled).
Source: World Bank 1997b (annex table A5.1).

tain competitive marketing efficiencies, government enterprises must be subject to the same constraints, incentives, and standards as private traders, collective farms, and grain processing companies. Competition could result in some government grain enterprises declaring bankruptcy and exiting the industry, leaving some of the 4.1 million grain bureau workers unemployed. But many of the grain bureaus would remain in business—with fewer workers. The cost of providing social assistance to all 4.1 million employees would be far less than the current inefficiency costs of 80 billion yuan.

Grain reserves

Industrial country governments have been getting out of grain storage because the cost of holding reserve stocks exceeds the perceived benefits of grain price stability, leaving reserves to be maintained as commercial stocks by more efficient and competitive private enterprises. Food grains in these countries comprise only a small portion of agriculture incomes and consumer spending, so price instability is relatively unimportant. But there are economic arguments for price stabilization in developing countries where food grains are a major cost element in the food basket.[20]

The China State Administration for Grain Reserves manages reserve stocks on a noncommercial basis. It directs and pays provincial grain bureaus to handle grain on its behalf. Separating the management and operational functions has hindered the government's ability to effectively stabilize prices. Price stabilization releases can be triggered by a 20 percent price increase, "within a short period of time" with State Council approval. Releases have been difficult to activate because the reserve grain is physically mixed with grain bureaus' commercial stocks, and it is sometimes sold and thus unavailable when needed. In addition, the grain bureaus are reluctant to release stocks because storage fees provide good income, and a substantial portion of the reserve stocks are unavailable.

The state grain reserve target of 40 million tons—together with reserves maintained by provincial and local authorities plus 90 million tons of commercial and semicommercial grain procured by state grain enterprises—is an extraordinary and costly quantity of grain to maintain price stability.[21] Price stability could surely be effected with smaller reserves. Provincial authorities and other jurisdictions maintain their own reserves, and farmers are known to retain large stocks. But information on stocks and releases is not available, so the costs and inefficiencies cannot be evaluated.

Large reserves protect against transitory insecurity, but less costly alternatives should be sought. Futures hedging is an efficient management tool when annual imports are required to meet consumption requirements but are inappropriate as insurance for possible imports. Futures options are relatively inexpensive theoretical alternatives, but there are too few market transactions in these instruments to be a viable alternative for China. However, if port and handling capacities are increased, greater reliance on the international market would be more efficient than maintaining stock for the most severe contingency. From 1990 to 1996 the average cost of internationally procured grain would have been $35 a ton less than procuring (at an international price equivalent) and storing domestic grain for subsequent use (table 3.7).

Policy proposals call for:

- Separate storage for incremental grains added to the reserve, and gradual stock removals from grain bureau storage to self-controlled storage.
- New grain warehouses, to be constructed in readily accessible grain-deficit locations.
- First-in, first-out inventory management.
- Reserves to be maintained independently of grain bureaus, using separate storage, staff, and accounts.
- Future reserves to be added as grains are available, not procured according to plan.

These changes would permit the State Administration for Grain Reserves to implement policy decisions and perform its stabilization role.

Input pricing and marketing

Fertilizer is the major cash input for food production, and its marketing remains a planned component of the input supply sector. Various government jurisdictions plan their fertilizer requirements and submit them to the next administrative level for consolidation, which must be approved by the State Planning Commission. The plan indicates the sources of domestic manufacturing and import requirements—including timing and port of delivery. The fertilizer supply market is basically a single channel monopoly operated by the China National

TABLE 3.7
Cost of maintaining versus importing wheat reserves
(U.S. dollars per ton)

Year	Purchase and carryover to following year[a]	Unit value of imports
1990		172
1991	220	118
1992	157	142
1993	185	129
1994	170	131
1995	172	174
1996	223	229

a. Assumptions include: 10 percent interest, 5 percent storage losses, and storage cost of $18 per ton a year.
Source: World Bank staff estimates.

Agricultural Means of Production Corporation, which takes domestically manufactured fertilizer from the manufacturers each week and receives imported fertilizer at the ports for onward distribution. Only an estimated 10 percent of the domestically manufactured fertilizer is traded outside this channel. Prices and marketing margins received by the corporation are government controlled. Imported fertilizer, which typically has higher nutrient content, is priced higher.

The Agricultural Means of Production Corporation at each level receives and sends fertilizer onward to the next lower level, eventually arriving at the farmers' villages. This system has been effective in supplying farmers with some nitrogen and phosphate fertilizers because the 1,500 small factories are widely distributed throughout the country and marketing basically involves moving local supplies over short distances. Interprovincial trade in fertilizers is primarily from imports.

This existing marketing structure has failed to deliver the types and combinations of fertilizer nutrients recommended and needed. Nor is it flexible enough to respond to the large and rapid changes in fertilizer quantities and composition required in the next century. Independent dealers, whose incomes depend on helping farmers to optimize their fertilizer input, work well in many countries of the world—and they should be an improvement in China.

International trading companies

China is the world's largest fertilizer importer—and in some years the world's largest grain importer. Imports of both commodities are "planned" up to six months before the beginning of the year and implemented by monopoly trading companies. Given China's importance in the international market, these companies impose considerable leverage in pricing and delivery terms, typically importing fertilizer and grain at c.i.f. (cost, insurance, freight) prices very near to international price levels.

The monopoly trading companies and "planned" import-export systems are effective, but they operate with uncertain efficiency. Planned grain trading has exacerbated fluctuations in rice, wheat, and corn supplies over the past decade. More open trade regimes might result in higher farmgate prices for corn, lower-cost wheat flour to consumers, and more stabilizing trade transactions.

Grain pricing

After a long period of very stable subsidized cereal prices, the government decided in 1993 to reduce its fiscal costs by increasing administratively set prices and moving toward market-determined prices. Domestic prices began to move upward in 1993, increasing sharply in 1994 before leveling off in 1995 and declining in 1996. By the end of 1996 wholesale cereal prices had returned to early 1994 levels. Throughout the period price movements were relatively smooth and without the monthly volatility experienced in the international market—particularly with rice. Nor were the international price spikes in late 1993 and early 1994 transmitted to domestic markets. But during 1994 domestic (wholesale) prices of corn increased 65 percent, rice 75 percent, and wheat 60 percent—while international prices of corn and rice were declining and wheat prices were stable. Both domestic and international prices peaked in early 1996, with domestic prices above international prices, and average domestic wholesale prices remain above international prices. But there is a very wide range of wholesale prices between the surplus and deficit provinces because the transport infrastructure is inadequate to move the large volumes required.

The combination of administratively determined procurement prices and planned imports and exports has hindered internationalization of the domestic market. With domestic prices now higher than international prices, domestic market liberalization and international integration are difficult. Reducing quotas and negotiated prices would hurt rural incomes and maintaining domestic prices above international levels would require import protection with either quotas or tariffs. Maintaining the current price differences implicitly subsidizes producers and requires large fiscal subsidies. Moreover, higher domestic grain prices encourage government grain enterprises to import rather than procure domestically. Thus China faces the prospect of unsanctioned cross-border trade—particularly with adjacent rice-exporting countries.

Water pricing

Water is the most limiting resource in food production, and current low water prices encourage overuse and greater scarcity. The Water Financial Directive of 1988 called for marginal-cost water pricing by 1997, but this clearly has not occurred. Water prices charged to most farmers remain below supply costs, ranging from zero to 0.40 yuan per cubic meter in the Yellow River Basin. The marginal value of water in agriculture ranges from 1 yuan per cubic meter for grains to 4 yuan per cubic meter for vegetables.[22] In the few locations where rational irrigation water pricing has been implemented, water demand has declined without affecting yields.

Water charges should thus be immediately increased to cover supply costs—with a timetable for the move to marginal cost pricing. Increasing prices may be difficult unless irrigation services and infrastructure are adequately maintained and system performance is improved.

Land use

Cultivation contracts for farmland were recently increased from 15 to 30 years. That improved incentives, but incentives remain inadequate to stimulate the investments needed to improve land productivity. And because land might be redistributed before contract expiration as rural households grow, land tenure remains insecure.[23]

Since many farmers, particularly in the southeast coastal provinces, now engage in agriculture part time and earn only a minor portion of their income from farming, they have little incentive for productivity-enhancing investments or practices (terracing, soil amelioration, degradation prevention). Such farmers are less interested in agricultural productivity than in retaining their land-use right as a social safety net.

Other farmers have begun to produce more profitable commodities, such as fruits, vegetables, livestock, and aquatic products. That leaves farmers who produce grain, oilseeds, and cotton at a serious income disadvantage—not because they lack scale economies but because of an inappropriate land and labor resource combination. Rural incomes will diverge even further unless grain producers can gain access to additional land. If they had access to the land of part-time farmers, with appropriate compensation, national productivity would increase.

The various land-use experiments under way, including shareholding and leasing village land, need to be expanded to facilitate the rapid development of a land-use market.

Notes

1. Total factor productivity is defined as the ratio of output to the weighted sum of inputs. It is typically expressed as a ratio of index numbers measuring the change in output relative to the change in total inputs.
2. Wen (1993, pp 1–41).
3. Lin (1992).
4. Huang, Rosegrant, and Rozelle (1996).
5. For example, Fan (all agriculture–China), Rozelle (rice–China), Griliches (hybrid corn–United States), Evenson and Jha (all agriculture–India), Pray and Ahmed (all agriculture–Bangladesh), and Thirtle and Bottomley (all agriculture–United Kingdom).
6. Fan and Pardey (1997).
7. Fan (1996).
8. Fan (1995).
9. Rozelle, Pray, and Huang (1996).
10. Rozelle, Pray, and Huang (1996).
11. Roselle, Pray, and Huang (1996).
12. The Consultative Group on International Agricultural Research is a loose-knit group of donors that support eighteen institutes engaged in international agricultural research.
13. Brown (1994).
14. Barren land may be either virgin land or abandoned cultivated land. Tidal lands are inundated during high tide and reappear during low tide, and wastelands are primarily areas where rocks and other waste materials from mining operations have been discarded.
15. Additional systems are under construction in the northeast, Yangtze River, and southwest areas under a World Bank Group-financed project.
16. Lloyd's Maritime Information Services, Inc. Also, during a recent 90-day period the average cost per ton for various bulk-grain shipments between the U.S. Gulf Coast and China were: 30,000 dwt, $31.00; 55,000 dwt=$25.00; and 80,000 dwt, $16.00. Fertilizer is frequently shipped in even smaller ships (15,000–25,000 dwt) with per ton rates in excess of $40.00.
17. Information Office of the State Council (1996).

18. Xinhua News Agency reports in various newspapers.

19. An estimated annual subsidy of 3 billion yuan for cotton was subtracted from the price subsidies for grain, edible oil, and cotton listed in *China Statistical Yearbook 1996*.

20. Rice price stabilization by Indonesia's Bulog (Badan Urusan Logistik) is estimated to have contributed almost 1 percentage point to GNP growth in its early years, 1969–74 (Timmer 1996).

21. Indonesia's Bulog stabilized domestic rice prices during the past three decades by relying heavily on private sector traders while itself performing only a marginal market role. Bulog's maximum annual rice purchase was 25 percent of production and carryover stocks are 1 million tons.

22. World Bank (1996).

23. Prosterman (1995).

chapter four

Food Supplies

An economic model and a constraints model were used to estimate future food production. The Global Trade Analysis Project (GTAP) general equilibrium model was modified to evaluate seven agricultural subsectors: rice, wheat, coarse grain, nongrain crops, livestock, meat and milk, and other food products. The extensive aggregation required to reduce general equilibrium models to manageable proportions results in some loss of detail, but the process ensures overall consistency (for details of the model, see World Bank 1997b). In this model agricultural growth is driven by investments and total factor productivity (TFP) growth, with production estimated under two TFP growth rates—1.0 and 0.5 percent. Lower investment would lead to a lower TFP growth rate.

Domestic grain projections

GTAP model results for 2020 indicate a grain production range of 707–769 million tons, depending on TFP growth, and meat production of 74 million tons—implying that meat production would be more efficient than meat imports. Coarse grain production would increase the most, reaching 258 million tons—with paddy rice reaching 361 million tons, and wheat, 150 million tons (table 4.1). These production estimates are extraordinarily high.

Because water is so severely limited in northern China, and the TFP growth rate may be reduced further even with increased investments in research, a physical constraints model was developed to evaluate the impact of various water options on agricultural output in the nine water regions. Containing no economic variables, it was estimated using three yield growth rates under conditions of favorable water availability. A continuously increasing yield growth rate of 1.0 percent annually (the high rate); a yield growth rate of 1.0 percent until 2010, with a subsequent growth rate of 0.5 percent (the base rate); and a yield growth rate of 1.0 percent up to 2000, with a subsequent growth rate of 0.5 percent (the low rate).

Estimated total grain output for 2020 in the constraints model is 636 million tons for the base case—considerably lower than the GTAP model estimates. Based on rainfall and water runoff statistics, the constraints model concluded that irrigation water will be limited in the northern corn-producing regions but remain sufficient in the southern rice-producing regions. That means that rice could become an important feed grain as well as a foodgrain. In many parts of southern China, low-quality hybrid rice is cheaper than coarse grains—and is already used for feed. As farmers gain experience in corn cultivation and new varieties specific to southern climates are developed, corn production will expand in the south. But producing rice as feed grain will likely continue—despite its lower feeding value—as hybrid rice yields are twice the corn yields in this region.

TABLE 4.1
Grain production estimates for 2020
(millions of tons)

Grain	GTAP model TFP growth 1.0	GTAP model TFP growth 0.5	Constraints model High	Constraints model Base	Constraints model Low
Rice[a]	361	342	313	298	283
Wheat	150	119	151	144	137
Coarse grains	258	256	203	194	186
Total	769	707	667	636	606

a. Measured as paddy equivalent.
Source: World Bank staff estimates.

The constraints model was also used to evaluate the impact on agriculture of alternative water allocations for nonagricultural (municipal and industrial) use, alternative yield growth rates (as a proxy for investment in research), and changes in effective irrigated area (as a proxy for water investments). The rate of industrial growth is the most influential factor in determining future irrigation water availability—and food production. In any given area the faster industry grows, the less water remains for agricultural use. Rapid industrialization in some water regions would exacerbate irrigation water shortages. Alternatively, industrialization in the water surplus areas of southern and southeastern China would not deprive agriculture of water. But the impact of transferring cultivated land to industrial use would be greater because the multiple cropping index is higher in the south than in the drier and colder north.

Results from the model clearly indicate the need for investments in water development, water saving, and water recycling to meet municipal and industrial requirements and to provide agriculture with incremental water supplies. In 2020 the marginal agricultural impact of the proposed south-north water transfer schemes (eastern and middle routes) would be about 15 million tons of grain, 10 million tons of vegetables, and various tonnages of other crops with a 1995 value of 57 billion yuan ($6.7 billion). That yields a crude internal rate of return of 20 percent for agriculture (no effort was made to determine incremental benefits to municipal and industrial users along the canal routes). The impact could be greater if scarce water were applied optimally, but for equity reasons, it is assumed that water shortages would be shared.

Besides the need for greater investment in water, the model also indicates the need to invest in land reclamation to maintain the cultivated and irrigated land base, agricultural research to ensure rising crop yields and expanded multiple cropping, and agricultural extension to transfer research results to farmers. The extension issue is particularly important for improving the fertilizer nutrient balance, because this would immediately increase productivity and provide a higher base for future productivity gains. If the fertilizer nutrient balance is not improved, grain supply deficits will likely double.

In the base case scenario for investments and water, cereal supply is estimated to be 636 million tons of rough grain in 2020, if the cultivated land base remains constant; 486 million tons of fruits and vegetables and 50 million tons of oilseeds would also be produced. This falls short of the expected needs of 695 million tons of grain, calling for imports of about 60 million tons of wheat and feed grains in about equal shares. About half the imports will be feed grains. If investments are inadequate to maintain the resource base and increase productivity, the lower production will demand even more imports.

The international grain market

In the early 1990s world grain production averaged 1.7 billion tons, half of it coarse grains, and wheat and milled rice accounting for the rest. About 11 percent of that production enters international trade—with wheat the most widely traded—followed by coarse grains and rice (table 4.2). China accounts for about 20 percent of world grain production, but its participation in world markets has been modest, at no more than 5 percent of international trade. However, the world grain market has the potential to supply China with substantially larger quantities.

The world markets for wheat and coarse grain are the largest and best integrated—with active cash and futures markets for wheat, maize, barley, oats, and rye. Smaller and less well integrated, the world market for rice is primarily centered in Asia. Operating as a cash market for private traders and government agencies, it is highly segmented by strong preferences for rice classes and qualities based on incomes, prices, and cultures. The world wheat market is less segmented but still has many classes of wheat—ranging from feed wheat for livestock to high-quality wheat for bread, pasta, and pastries. Coarse grains, used primarily for animal feed, are traded based on feed value.

TABLE 4.2
Annual average world grain production and trade, 1992/93–1996/97
(millions of tons)

Grain	World production	China's production	China's share of world production (percent)	World trade
Coarse grain	839.7	100.6	12.2	90.3
Wheat	551.1	115.0	20.8	98.7
Rice (milled)	367.0	128.7	35.8	12.1
Total	1,759.6	344.3	19.8	201.1

Source: USDA/FAS 1996.

Potential grain export supplies

The potential supply of grain from the world market is substantially larger than today's trade of 200 million tons, but stagnant world import demand since the late 1970s has delayed development of this potential. The traditional grain exporters accounted for 90 percent of world grain exports in the first half of the 1990s.[1] Domestic per capita consumption is already high in these countries, and, except for Thailand, population growth is low—so production growth is primarily a function of their ability to export. With reduced export demand, they reduced grain crop areas by 34.5 million hectares from the highs of the early 1980s. The production potential of this land was roughly 115 million tons, and it could be returned to production almost immediately if there were incentives to do so, as shown by increases in 1996 cereal plantings and harvest.

In addition to the cropland that could be returned to grain production in these exporting countries, there are other potential sources of export supplies:

- The former Soviet Union has since the early 1980s reduced the cropland used for grain production by 27 million hectares, and due to fuel, fertilizer, and machinery shortages and to marketing and transportation constraints, its total production declined by 86 million tons between 1990 and 1995.
- Argentina has 142 million hectares of permanent pasture, flat delta land used primarily for cattle grazing, and only 2.2 million hectares of permanent crops.[2] With only a small portion of the land receiving fertilizers, pesticides, or herbicides, much could be used for crop production under improved production practices.
- Export grain stocks in the major exporting countries are about 100 million tons, some 40 million tons above the previous low of 60 million tons in 1995–96.[3] So world trade could immediately expand by roughly 40 million tons, and over the longer term the potential for

increased grain supplies is large. For example, in response to higher prices in 1996–97 production in the five largest exporters increased by 20 percent.

World grain price volatility

Historically, world grain prices have declined over long periods relative to overall consumer prices, but they have also increased sharply over short periods of two to three years. Real average annual prices for wheat, maize, and rice declined 50 to 60 percent between the 1970s and the 1990s.[4] But between 1971 and 1974 real prices of all major grains increased by 50 to 100 percent, due primarily to a rapid rise in energy and fertilizer prices. Also, between 1993 and early 1996 real prices increased 33 percent for wheat and 46 percent for corn but then declined (table 4.3).

Real grain price declines are forecast over the next ten to fifteen years, according to recent studies by researchers at the World Bank, the UN Food and Agriculture Organization, and the International Food Policy Research Institute.[5] These forecasts assume that historical yield increases continue, that population growth slows, and that demand increases due to rising incomes.

Future grain price volatility is likely to increase because of policy changes in the major exporting countries—those due to the Uruguay Round Agreement on Agriculture and those made unilaterally in the United States and the European Union for budgetary reasons. Policy changes in the major grain exporting countries were largely responsible for the sharp declines in world grain stocks between 1986 and 1995. These changes will keep world grain stocks low because the United States government will no longer hold significant grain stocks, and stock-holding is expected to be lower in the European Union. Lower stocks could lead to greater price volatility because the buffer against a poor harvest is less. But the major grain-exporting countries have been highly responsive to international prices and the level of world demand.

TABLE 4.3
World grain prices, selected periods 1991–96
(nominal U.S. dollars)

Period	Wheat	Rice	Maize
1991 (annual average)	128.66	314.40	107.40
1993 (annual average)	140.24	270.00	102.10
1996 (January–June average)	231.40	349.60	183.00
1996 (December average)	175.70	319.20	117.70

Source: World Bank staff estimates.

Large-country effect

If China were to increase grain imports significantly and rapidly, its actions would push up world grain market prices. But if imports were gradually increased over several years, the price impact would be marginal.

The level of grain stocks is important because it reflects the ease of expanding exports. During the mid-1980s, the major grain-exporting countries had carry-over grain stocks of 260 million tons, while world grain trade was less than 200 million tons. This large reserve could expand exports without significant price increases. In contrast, current world grain stocks of about 100 million tons could not meet a significant increase in exports. The price elasticity of export supply is lower now than during the mid-1980s—roughly 1.1.[6] In the longer term (say, after five years), export supply is more elastic because producers have more time to expand production.

Market access

Concern about market access has often led to policies aimed at a high degree of self-sufficiency in traditional food-importing countries, stimulated by the poor policy record of the major grain exporters. In 1996 the European Union imposed a wheat export tax in an attempt to reduce exports and prevent domestic prices from rising. During the 1970s the United States embargoed either soybeans or grain in three successive years to prevent higher consumer prices. Targeted export embargoes have also been used for political reasons, as in 1980, when the United States embargoed grains, other foods, and agrochemical exports to the former Soviet Union to protest the invasion of Afghanistan. But this sixteen-month embargo was largely ineffective because alternative supplies were available.

Exporting countries often limit food exports if prices rise sharply, so unless an importing country has a long-term agreement, supplies from individual countries are not assured. Further, those supplies are least likely to be available when prices rise sharply—precisely when market access is most important. The best defense for importing countries is to diversify imports among competing suppliers and to enter long-term agreements that specify conditions for market access.

Meeting future demand

With appropriate incentives, grain output in the exporting countries (including the former Soviet Union) could increase by 200 million tons and bring them to their previous maximum output levels. But most regions of the world are net importers and will require increased imports. So the issue is whether the traditional exporters (including countries of the former Soviet Union) can meet all the incremental import requirements without large price increases.

In the early twenty-first century most of the incremental demand will be met from domestic production, except for Japan, the Republic of Korea, and Taiwan (China). But worldwide import requirements will triple (increase 200 percent) between 1990–94 and 2030. To meet this requirement, production in the exporting countries will need to grow by 1.1 to 1.4 percent a year—readily attainable if investments in research are maintained.

Notes

1. The traditional grain exporters and their share of total world exports are as follows: the United States (42 percent), the European Union (22 percent), Canada (11 percent), Australia (7 percent), Argentina (6 percent), and Thailand (2 percent).
2. FAO (1995).
3. USDA/FAS (1996).
4. World Bank (1997b).
5. Islam (1995).
6. Carter and Gardiner (1988). Consider the export supply elasticity of the five major grain exporters. The 1990–95 average grain production of these countries was 583 million tons, domestic consumption was 432 million tons and exports were 185 million tons. If we assume a domestic demand and supply elasticity of 0.2 and that stock holdings will remain constant, then the export supply elasticity is 1.10. If we assume a domestic demand and supply elasticity of 0.1 then the export supply elasticity is 0.55, and if the domestic demand and supply elasticity is 0.3 then the export supply elasticity is 1.65.

chapter five

Food Balance Options

China has the potential to remain food secure over the next two to three decades if it carries out reforms and makes investments in agriculture and infrastructure. China is expected to rely more on market forces to signal investment, production, and consumption decisions. And once it joins the World Trade Organization, it will integrate more fully with the international marketplace. If all this is successful, domestic food production will keep pace with population growth, but household food security may remain problematic for the poor.

With a more open trade regime and competitive market, China and its trading partners will benefit through exploiting their comparative advantages. Increased incomes and urbanization will change diets: direct grain consumption (per capita) will decline, and the consumption of livestock products (indirect grain consumption), vegetable oils, sugar, fruits, and vegetables will increase.

China can substantially increase domestic grain production, but irrigation shortages will limit expansion, and the country will have to rely more on the international market for wheat and feed grains.

Options

The best estimate of China's 2020 cereal demand is about 608 million tons (697 million tons of unmilled grain), but actual requirements depend on several uncertain factors. Domestic production can meet a major part of the incremental needs if investments are made to:

- Improve agricultural research and extension to maintain total factor productivity growth and rapidly achieve balanced fertilizer application.
- Develop water resources to enable aggregate supplies of irrigation water—including recycling and reuse—to increase by an average of 0.5 percent annually between 1995 and 2020. Achieving this will require water transfers from the Yangtze to the Yellow River Basin.
- Reclaim and develop land to maintain the current stocks of arable and irrigated land.
- Develop dedicated port and rail facilities for integrated bulk-handling and transport of larger quantities of domestic and imported grains. (Without such investments even greater investments would be needed in covered rail wagons, bag-handling equipment, and flat storage—as well as in suboptimal agricultural production and water resource development throughout China.)

A series of policy reforms centered on less government intervention in the cereal sector, market-determined prices, and open competitive marketing and trading regimes for inputs and cereals must accompany these investments. With these investments and reforms, China will likely produce 90 percent of its grain requirements and rely on international suppliers for the balance—about 60 million tons of grain by 2020. But without them, more imports will be required. The major grain-exporting countries could readily supply these added imports, but unless China invests heavily in port facilities and bulk logistical systems, imported grain will be extremely costly because even greater investments would be needed to improve the present outmoded handling systems.

Domestic grain supplies

Government would like to maintain 95 percent grain self-sufficiency, but to limit future imports to 5 percent of consumption would be inefficient and costly. To achieve 95 percent self-sufficiency, import tariff protection of about 25 percent would be required and domestic wholesale prices would be about 50 percent higher than international prices.

Pricing and marketing

To improve food security, grain production, and marketing efficiency, China must reduce government intervention and increase its reliance on market forces to determine prices of both inputs and outputs.

More reliance on market forces could improve efficiency. To achieve and maintain marketing efficiency, government grain enterprises and nongovernment marketing agencies must operate under the same constraints, the same efficiency incentives, and the same commercial standards. To ensure that markets are integrated and farmers receive proper price signals, the government must discontinue the spatial and temporal monopoly-monopsony privileges of its grain enterprises and eliminate below-market-price procurement. It must also relax countryside procurement constraints on the grain enterprises from deficit areas and on private traders. Instead, the government should procure grain for the poor, military forces, civil servants, and strategic reserves at competitive "market" prices and transfer its policy functions to other noncommercial agencies. Similarly, monopoly fertilizer marketing must be discontinued.

Water is the major constraint to expanding food production in China. But inappropriately low irrigation water prices have encouraged inefficient water use and have led to water shortages. To improve water-use efficiency, including irrigation, the government must increase water prices to cover supply costs and then establish a timetable to increase prices to long-run marginal cost levels. Also, market-determined freight tariff rates would encourage the development of more efficient transport modes, such as bulk barge carriers.

Price stabilization can be less costly. Price stabilization is possible with considerably less market participation than the 70–80 percent of marketed surpluses that government grain enterprises currently procure. If the state wishes to stabilize prices and maintain strategic grain reserves, these activities should be managed and operated by a government agency completely separate from the commercial operations of government grain enterprises. The stabilization programs should operate within price bands that generally follow long-term international price trends. Otherwise, costs will become exorbitant and unsustainable.

Changes in land policies could boost food production. Two changes in land policies could provide incentives to increase land productivity and food security and to improve rural income distribution. One is allowing rural residents to lease their land cultivation rights to others (when off-farm activities provide most of their income) or to lease cultivation rights from others when underemployed on their own farms (which also would improve rural income distribution). The other is encouraging the private sector to invest in land reclamation. In addition, the rural land experiments now under way should be evaluated, consolidated, legalized, and publicized—to enable farmers and land developers to understand the alternatives and the opportunities.

International trade policies should be relaxed. The monopoly trading corporations have procured and imported fertilizer and grains at prices very close to international prices. But farmers have not been provided with the appropriate balance of fertilizers. And because supply-demand conditions change between planning and execution, planned international transactions have amplified the volatility of domestic supply. Planned trade and trade monopolies should be discontinued so that open trading can facilitate appropriate imports, permit timely exports, prevent unnecessarily large corn stocks from accumulating in the northeast provinces, and ensure that imported commodities are procured and handled efficiently.

Research and resource investments

Agricultural research is an excellent investment, but research must have priorities, and research budgets must be increased. China has had a dynamic agricultural research system, but agricultural research intensity has declined over the past fifteen years, raising doubts about its ability to sustain long-term growth in total factor productivity.

Research indicates that balanced fertilizer application would increase land productivity by 12 to 15 percent—increasing cereal production by 50 to 60 million tons. Whether the failure to apply balanced fertilizers lies within the agricultural extension system or the fertilizer market structure, the constraints must be identified and resolved.

Developing China's fertilizer industry will require large investments with long lead times. China has sufficient feedstock material to develop large-scale ammonia-urea manufacturing plants to meet new nitrogen requirements and replace a portion of the low-analysis ammonium bicarbonate plants. Also, the richer phosphate deposits are being exploited, but earlier planned investments in accompanying triple superphosphate manufacturing plants have not materialized.

Water is the most limiting food production resource. Increasingly, water will be diverted from agricultural to urban and industrial uses, and large investments will be required to maintain and increase irrigation water supplies. A first step is to improve efficiency by treating and recycling municipal wastewater, lining canals, and improving on-farm application. Municipalities and industries must be required to invest in wastewater treatment to permit environmentally safe recycling.

Water resources development is costly and has high social returns but low financial returns. Except for small pond- and reservoir-based irrigation systems, only the government has the capacity to undertake new investments like the water transfers from the Yangtze to the Yellow River Basin, which require long-term planning and huge investments.

China's per capita cultivated land base is quite small, but satellite imagery shows that it is 40 percent larger than official statistics indicate. This means that fertilizer application rates and crop yields are 40 percent below reported levels—representing tremendous potential for increasing productivity and production. Continued investments in land reclamation are required to maintain the land base. Though newly reclaimed land is less productive than the prime agricultural land it replaces, it is needed to compensate for the land lost to urban encroachment and infrastructure construction.

Rising urbanization and cereal-based livestock production mean that more grain will be marketed, handled, and transported. Investment in improved handling infrastructure is essential for moving these increased quantities of grain efficiently. This includes dedicated bulk grain-handling logistical systems involving inland and coastal waterways, rail, transit storage, and intermodal transfers.

Large investments will be required to efficiently produce 636 million tons of cereals and import another 60 million tons and to undertake routine maintenance and capital replacement. Water resource development involving south-north transfers, improved irrigation canals and distribution systems, and municipal-industrial wastewater treatment will require the largest investment. Other large investments will be needed in transportation and handling infrastructure, including ports, bulk rail, and waterway transport; ancillary bulk-handling equipment; and fertilizer manufacturing. Also, investment and current budgets will need to be increased for agricultural research and extension. Rough estimates of incremental investment requirements are indicated in table 5.1.

Incentives for nonstate investments

The government alone will not be able to finance the large investments required to provide future food security. Incentives will be needed for nongovernment investments:

- International seed companies might invest in research in China if permitted and if intellectual property rights were strengthened, but most agricultural research will need to be funded from domestic public resources.
- International fertilizer companies might invest in China's domestic industry. This would partially resolve the fertilizer investment constraint and ensure that the latest mining and manufacturing technology is employed.
- Land reclamation and long-term productivity-enhancing measures require incentives for nonstate sectors to invest. These might include extended cultivation rights or the privilege of leasing out cultivation rights and compensation for land reclamation companies through land sales or leases (with government retaining ownership) perhaps for nonagricultural use. Longer-term contracts for farmers might induce them to terrace or undertake other land improvements.
- Incentives for nonstate investors in domestic marketing and transportation infrastructure are difficult to design, but large domestic and international corporations (such as Chai Tai) might invest in bulk transit storage and bulk barge or rail wagons, if these were dedicated to their operations. And, if the grain market were more open, international grain corporations might invest in ports and bulk-handling equipment. Without major private participation in grain markets, transport and logistical investments in high-volume grain corridors would probably depend on the public treasury.

TABLE 5.1
Estimated incremental investment requirements, 1995–2020
(millions of 1995 U.S. dollars)

Water resources	64,000
South-north water transfer	25,000
Irrigation distribution improvement[a]	39,000
Municipal-industrial wastewater treatment	n.a.
Infrastructure	1,385
Ports	600
Bulk rail wagons	625
Bulk barges	90
Inland terminals, with bulk-handling equipment	70
Fertilizer manufacturing plants	5,000
Agricultural research[b]	25,660
Agricultural extension	n.a.
Total	96,045

n.a. Not available.
a. To maintain the trend of the past decade, investments in water conservation should increase by about $120 million annually; expenditures in 2020 should be $3 billion more (in 1995 terms) than in 1995.
b. To maintain the trend of the reform period, agricultural research investments should increase by 5 percent annually; investment expenditures in 2020 should be $1.75 billion more (in 1995 terms). This may or may not be enough to maintain total factor productivity growth at 1.0 percent a year.
Source: World Bank staff estimates.

The international market

International grain stocks have been rebuilt to about 100 million tons from the lows of 1995–96, creating a small margin for increased trade. But the major grain-exporting countries could rapidly produce and export much larger quantities of grain if they expected steady growth in export demand.

International grain prices are expected to continue their long-term decline. But short-term volatility is likely to be greater than during previous decades because the exporting countries have discontinued or reduced government storage, leaving a smaller buffer to mitigate shortages from drought or calamity. It would be to China's advantage to enter long-term contracts for specified quantities of grain with grain traders from exporting countries.

China's fourteen major grain ports have a theoretical import capacity of 23 million tons—they were at 85 percent of capacity in 1995 when total imports were 20 million tons. Although these and other ports could handle more grain, it would be very costly to import beyond design capacity because marginal costs increase rapidly. That makes it crucial to construct deep-water ports capable of handling 80,000 dwt vessels and to link bulk grain logistical systems with port facilities.

As China continues to open to the world, its options for achieving food security will increase. Both China and its trading partners will benefit from exercising their comparative advantages in an increasingly dynamic world market. Investments in agriculture will enable China to increase its domestic food production, and investments in infrastructure mean that food surpluses and food imports can be efficiently transferred throughout the country. Expanded options for food security will mean greater variety and abundance at China's table.

References

Ahuja, Vinod, and D. Filmer. 1995. "Educational Attainment in Developing Countries: New Estimates and Projections Disaggregated by Gender." Background Paper for the *World Development Report 1995*. World Bank, World Development Report Office, Washington, D.C.

Alexandratos, N. 1997. "China's Consumption of Cereals and the Capacity of the Rest of the World to Increase Exports." *Food Policy*. 22(3): 253–69.

Anderson, K., B. Dimaranan, T. Hertel, and W. Martin. 1996. "Asia-Pacific Food Markets and Trade in 2005: A Global, Economy-wide Perspective." CEPR Discussion Paper 1474. Center for Economic Policy Research, London.

Aubert, C. 1996. "China's Grain Distribution and Price Policies." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Barichello, Richard. 1996. "The Nature of State Trading in Indonesia: The Case of BULOG." Paper presented at the International Agricultural Trade Research Consortium annual meeting, December 15–17, Washington, D.C.

Brown, Lester R. 1994. "Can China Starve the World? Its Booming Economy Is Consuming Global Food Supplies." *Washington Post*, August 28.

———. 1995. *Who Will Feed China? Wake-up Call for a Small Planet*. New York: W. W. Norton & Company.

Cao, Mingkui, Shijin Ma, and Chunru Han. 1994. "Potential Productivity and Human Carrying Capacity of an Agro-Ecosystem: An Analysis of Food Production Potential of China." *Agricultural Systems* 47(March): 387–414.

Carter, Colin A., and Walter H. Gardiner, eds. 1988. *Elasticities in International Agricultural Trade*. Boulder, Colo.: Westview Press.

Chern, Wen S. 1997. "Survey of Food Demand Elasticities in China." Background paper for this report. World Bank, East Asia and the Pacific Region, Rural Development and Natural Resources Sector Unit, Washington, D.C.

China State Statistical Bureau. Various years. *China Statistical Yearbook.* Beijing: China Statistical Press.
———. 1987. "Input-Output Table of China 1987." Beijing.
———. 1992. "Input-Output Table of China 1992." Beijing.
Chu, A.C.P. 1996. "Sustainable Agriculture: Integrating Pastoral and Arable Land in Southern China; A Model to Increase Arable Land—What Can the New Zealand Experience Contribute?" Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.
Crook, F. W. 1996. "How will China's 'Rice Bag Policy' Affect Grain Production, Distribution, Prices and International Trade?" Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.
Du, Ying. 1996. "Perfection and Reforms of Chinese Food Production and Marketing Policies." Paper presented at the International Symposium on Food and Agriculture in China—Perspectives and Policies, October 7–9, Beijing.
Evenson, R. E., and D. Jha. 1973. "The Contribution of Agricultural Research Systems to Agricultural Production in India." *Indian Journal of Agricultural Economics* 28: 212–30.
Fahlbeck, E., and Z. Huang. 1996. "The Property Right Structure of Farm Land and Family Farming in China—An Analysis of Developing Options." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.
Fan, Shenggen. 1991. "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture." *American Journal of Agricultural Economics* 73(2): 266–75.
———. 1995. "Data Survey and Preliminary Assessment in China." Report to the United Nations Food and Agriculture Organization, January 30, Rome.
———. 1996. "Research Investment, Input Quality, and the Economic Returns to Chinese Agricultural Research." Paper presented at the China Workshop—Global Agricultural Science Policy for the 21st Century, August 26–28, Melbourne, Australia.
Fan, Shenggen, and Mercedita Agcaoili-Sombilla. 1996. "Why Projections on China's Future Food Supply and Demand Differ." Paper presented at a conference on Food and Agriculture in China: Perspective and Policies, October 7–9, Beijing.
Fan, Shenggen, and Philip G. Pardey. 1992. *Agricultural Research in China: Its Institutional Development and Impact.* The Hague: International Service for National Agricultural Research.
———. 1997. "Research, Productivity and Output Growth in Chinese Agriculture." *Journal of Development Economics* (June).
FAO (Food and Agriculture Organization). 1995. "The State of Food and Agriculture." Rome.
———. 1996. *Balance Sheets, 1992–94.* FAO Statistical Series 131. Rome.
Feng, Lu. 1996. "Feed Demand and its Impact on Grain Economy in China." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.
Food Studies Group. 1996. "Global Cereal Markets and Food Security." Paper presented at the International Development Center, Queen Elizabeth House, April, Oxford.
Garnaut, Ross, and Guonan Ma. 1992. *Grain in China.* Canberra, Australia: Department of Foreign Affairs and Trade, East Asia Analytical Unit.
Glenshaw, Peter A. 1996. "The Role of Fertilizers in Food Security—The Case of China." Paper presented by Sulfur Institute at fifth biennial symposium: Sulfur Markets—Today and Tomorrow, March 28, Washington, D.C.
Griliches, Z. 1958. "Research Costs and Social Returns: Hybrid Corn and Related Activities." *Journal of Political Economics* 66(October): 419–31.
GTAP (Global Trade Analysis Project). 1996. GTAP Database, version 3.3. Purdue University, West Lafayette, Ind.
Guanzhong, James Wen. 1993. "Total Factor Productivity Change in China's Farming Sector: 1952–1989." *Economic Development and Cultural Change* 42(1): 1–41.
Hertel, T. W. 1997. *Global Trade Analysis: Modeling and Applications.* Cambridge: Cambridge University Press.
Hong, Y. 1996. "Sources of Productivity Disparities in Regional Grain Production in China." Paper presented at the China Workshop—Global Agricultural Science Policy for the 21st Century, August 26–28, Melbourne, Australia.
Huang, Jikun. 1996. "China's Integration into the Global Economy: Longer Term Implications for Agriculture and the Agro-Food Sector." Center for Chinese Agricultural Policy, Chinese Academy of Agricultural Sciences, Beijing.
Huang, Jikun, and Howarth Bouis. 1996. "Structural Changes in the Demand for Food in Asia." Food, Agriculture and the Environment Discussion Paper 11. International Food Policy Research Institute, Washington, D.C.
Huang, Jikun, and Scott Rozelle. 1995. "Environmental Stress and Grain Yields in China." *American Journal of Agricultural Economics* 77 (4): 853–64.
———. 1996. "Technological Change: Rediscovering the Engine of Productivity Growth in China's Rural Economy." *Journal of Development Economics* 49 (July):337–69.
Huang, Jikun, and L. Zhang. 1996. "The Macroeconomic and Public Expenditure Implications of Grain Policies in China: Some Selected Issues for Discussion." Paper presented at the workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.
Huang, Jikun, M. Rosegrant, and Scott Rozelle. 1996. "Public Investment, Technological Change and Reform: A Comprehensive Accounting of Chinese Agricultural Growth." Paper presented at the China Workshop—Global Agricultural Science Policy for the 21st Century, August 26–28, Melbourne, Australia.
———. 1997. "China's Food Economy to the Twenty-first Century: Supply, Demand and Trade." Food, Agriculture and the Environment Discussion Paper 19. International Food Policy Research Institute, Washington, D.C.
Huang, Yanxin. 1995. "Current Demand for Grain in China and Forecast Until 2000." Paper presented at a conference on Grain Market Reform in China and Its Implications, East and West Centre, September 16–19, Honolulu.
Huffman, Wallace E., and Robert E. Evenson. 1989. "Supply and Demand Functions for Multiproduct U.S. Cash Grain Farms: Bias Caused by Research and Other Policies." *American Journal of Agricultural Economics* 71: 761–73.
IFPRI (International Food Policy Research Institute), Environment and Production Technology Division. 1995. "Data Survey and Preliminary Assessment of Agricultural Investment in China." A Report to the United Nations Food and Agriculture Organization. New York.
Information Office of the State Council. 1996. *The Grain Issue in China.* Beijing.
Islam, Nurul, ed. 1995. *Population and Food in the Early Twenty-first Century: Meeting Future Food Demand of an Increasing Population.* Washington, D.C.: International Food Policy Research Institute.
Islam, N., and S. Thomas. 1996. *Food Grain Price Stabilization in Developing Countries: Issues and Experiences in Asia.* Food Policy Review 3. Washington, D.C.: International Food Policy Research Institute.
Johnson, G. L., and L. Quance. 1972. *The Overproduction Trap in U.S. Agriculture.* Baltimore, Md.: Johns Hopkins University Press.

Kalirajan, K. P., and Yiping Huang. 1996. *An Alternative Method of Measuring Economic Efficiency: The Case of Grain Production in China.* Adelaide, Australia: University of Adelaide.

Lardy, Nicholas. 1983. *Agriculture in China's Modern Economic Development.* Cambridge: Cambridge University Press.

———. 1992. "Rural Reforms and Agricultural Growth in China." *American Economic Review* 82(1): 34–51.

Lin Bao, Lin Jixiong, and Li Jiakang. 1996. *The Significance of Balanced Fertilization, Based on Results from Long-Term Fertilizer Experiments.* Balanced Fertilizer Situation Report 2. Beijing: Chinese Academy of Agricultural Sciences, Soil and Fertilizer Institute.

Lin, Justin Yifu. 1992. "Rural Reforms and Agricultural Growth in China." *American Economic Review* 82: 34–51.

Lin, Justin Yifu, and Minggao Shen. 1994. "Rice Production Constraints in China: Implication for Biotechnology Initiative." Paper presented at the International Workshop on Rice Research Prioritization in Asia, February 15–22, Los Baños, Philippines.

Lin, J., J. Huang, and S. Rozelle. 1996. "OECD Forum for the Future." Paper presented at the Conference on China in the 21st Century: Long-term Global Implications, China's Food Economy: Past Performance and Future Trends, January 8–9, Paris.

Lin, X., C. Yin, and S. D. Xu. 1996. "Maximizing Sustainable Rice Yields through Improved Soil and Environmental Management." Paper presented at the International Symposium on Food and Agriculture in China's Perspectives and Policy, October 7–9, Beijing.

Liu, Shaoqiu. 1992. "The Impact of Irrigation on Agricultural Productivity in China." Ph.D. Dissertation, Department of Agricultural Economics, University of the Philippines, Los Baños.

Lucas, Robert E., Jr. 1967. "Adjustment Costs and Theory of Supply." *Journal of Political Economics* 75(August): 321–34.

Ma, X. 1996. "Grain Price Variance in China and Its International Comparison." Paper presented at the International Symposium on Food and Agriculture in China: Perspectives and Policy, October 7, Beijing.

McMillan, J., J. Whalley, and L. Zhu. 1989. "The Impact of China's Economic Reforms on Agricultural Productivity Growth." *Journal of Political Economy* 97: 781–807.

Mei Fangquan. N.d. "Sustainable Food Production and Food Security in China." Chinese Academy of Agricultural Sciences, Beijing.

———. 1996. "Prospects and Strategic Options of Food and Agricultural Production in China." Chinese Academy of Agricultural Sciences, Beijing.

Nehru, V., and A. Dhareshwar. 1993. "A New Database on Physical Capital Stock: Sources, Methodology, and Results." *Revista de Análisis Económico.* 8: 37–59.

Pardey, Phil, R. Lindner, E. Abdurachman, S. Wood, S. Fan, W. Eveleens, B. Zhang, and J. Alston. 1992. "The Economic Returns to Indonesian Rice and Soybean Research." Report prepared for the Agency for Agricultural Research and Development (AARD) and the International Service for National Agricultural Research (ISNAR).

Potash and Phosphate Institute and Potash and Phosphate Institute of Canada. 1996. "Interpretive Summaries: North American and International Research Projects." Saskatoon.

Pray, C.E., and Z. Ahmed. 1991. "Research and Agricultural Productivity Growth in Bangladesh." In R.E. Evenson and C. E. Pray, eds., *Research and Productivity in Asian Agriculture.* Ithaca, New York: Cornell University Press.

———. 1991. "Research, Productivity and Incomes in Asian Agriculture." In R.E. Evenson and C. E. Pray, eds., *Research and Productivity in Asian Agriculture.* Ithaca, New York: Cornell University Press.

Prosterman, Roy, and Tim Hanstad. 1995. "Land Reform: Neglected, Yet Essential." Rural Development Institute Report 87. Seattle.

Rae, Allan N. 1996. "China's Development, Food Consumption and Livestock—Feeds Policy Interactions." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Rosegrant, M. W., M. Agcaoili-Sombilla, and N. D. Perez. 1995. "Global Food Projections to 2020: Implications for Investment." Food, Agriculture and the Environment Discussion Paper 5. International Food Policy Research Institute, Washington, D.C.

———. 1997. "Global Food Projections to 2020: Implications for Investment." 2020 Vision Discussion Paper Series 5, International Food Policy Research Institute, Washington, D.C.

Rozelle, Scott, Carl Pray, and Jikun Huang. 1996. "Agricultural Research Policy in China: Testing the Limits." Paper presented at the China Workshop—Global Agricultural Science Policy for the 21st Century, August. 26–28. Melbourne, Australia.

Schwartz, L.L., A. Sterns, J.F. Oehmke, and R.D. Freed. 1989. "Impact Study of the Bean/Cowpea Collaborative Research Support Program (CRSP) for Senegal." Michigan State University, Department of Agricultural Economics, East Lansing.

Scobie, M., and I.R. Posada. 1978. "The Impact of Technical Change on Income Distribution: The Case of Rice in Colombia." *American Journal of Agricultural Economics* 60(1): 85–92.

Sicular, Terry. 1991. "China's Agricultural Policy During the Reform Period." In Joint Economic Committee, Congress of the United States, ed., *China's Economic Dilemmas in the 1990s: The Problems of Reforms, Modernization and Interdependence.* Washington, D.C.: U.S. Government Printing Office.

Simpson, J. R. 1996. "Animal Feed Requirements and Availabilities in China—Projections and Policies." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Smil, Vaclav, 1993. *China's Environmental Crisis: An Inquiry into the Limits of National Development.* New York: ME Sharpe.

Song, H. 1996. "China's Agricultural Infrastructure Construction and Investment Policy." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Stauffer, Mark D., and James D. Denton. 1995. "Importance of Plant Nutrients in Increasing Agricultural Productivity—Chinese Experience." Paper presented by the Potash and Phosphate Institute of Canada at the Fertilizer Association of India's annual general meeting, December 7–9, New Delhi.

Stone, B. 1993. "Basic Agricultural Technology under Reform." In Y.Y. Kueh and Robert F. Ash, eds., *Economic Trends in Chinese Agriculture: The Impact of Post-Mao Reforms.* Oxford: Clarendon Press.

Tang Renjian. 1996. "The Reform on Grain Policy: Difficulties and Objectives—Reflections on China's Grain Problem." Paper presented at the International Symposium on Food and Agriculture in China: Perspectives and Policy, October 7–9, Beijing.

———. 1996. "The Reform of the GCS in China: Present Situation, Target and Ways." Paper presented at the International Symposium on Food and Agriculture in China: Perspectives and Policy, October 7–9, Beijing.

The People's Republic of China. 1996. "Food Security in China." Contributed to the World Food Summit, November, Rome.

Thirtle, C., and P. Bottomley. 1988. "Is Publicly Funded Agricultural Research Excessive?" *Journal of Agricultural Economics* 31(1): 99–111.

Timmer, C. Peter. 1990. "How Does Indonesia Set Its Rice Price? The Role of Markets and Government Policy." Paper presented at the International Conference on the Economic Policy Making Process in Indonesia, September 6–9, Bali.

———. 1991. "Food Price Stabilization: Rationale, Design and Implementation." In D. H. Perkins and Michael Roemer, eds., *Reforming Economic Systems in Developing Countries.* Cambridge: Harvard Institute for International Development.

———. 1996. "Does BULOG Stabilize Rice Prices in Indonesia? Should It Try?" *Bulletin of Indonesian Economic Studies* 32(2): 45–74.

Tin, Nguyen, Cheng Enjiang, and Christopher Findlay. 1996. *Land Fragmentation and Farm Productivity in China in the 1990s.* Adelaide, Australia: University of Adelaide.

USDA/ERS (U.S. Department of Agriculture, Economic Research Service). 1996. "Long-Term Projections for International Agriculture to 2005." ERS Staff Paper 9612. Washington, D.C.

USDA/FAS (U.S. Department of Agriculture, Foreign Agriculture Service). 1996. "Grain: World Markets and Trade." GF10-96. Washington, D.C.

Wang, Zhi, and J. Kinsey. 1994. "Consumption and Saving Behavior under Strict and Partial Rationing." *China Economic Review* 5(1): 83–100.

Wen, G. J. 1993. "Total Factor Productivity in China's Farming Sector: 1952–1989." *Economic Development and Cultural Change,* 42:(1) 1–41.

World Bank. 1991. "China—Managing an Agricultural Transformation, Grain Sector Review." Report 8652-CHA. East Asia and Pacific Regional Office, China and Mongolia Department, Agricultural Operations Division, Washington, D.C.

———. 1993a. "China—Grain Distribution and Marketing Project." Staff Appraisal Report 11671-CHA. East Asia and Pacific Regional Office, China and Mongolia Department, Agriculture Operations Division, Washington, D.C.

———. 1993b. "China—Yellow River Basin Investment Planning Study." Report 11146-CHA. East Asia and Pacific Regional Office, China and Mongolia Department, Agriculture Operations Division, Washington, D.C.

———. 1995a. *Global Economic Prospects and the Developing Countries 1995.* Washington, D.C.

———. 1995b. "World Population Projection 1994–95." Washington, D.C.

———. 1997a. "China—Forward with One Spirit: A Strategy for the Transport Sector." Report 15959-CHA. East Asia and Pacific Regional Office, China and Mongolia Department, Infrastructure Operations Division, Washington, D.C.

———. 1997b. "China: Long-Term Food Security." Report 16419-CHA. East Asia and Pacific Regional Office, China and Mongolia Department, Rural and Social Development Operations Division, Washington, D.C.

———. Various issues. *Commodity Markets and the Developing Countries.* International Economics Department. Washington, D.C.

Wu, Harry X., and Christopher Findlay. 1996. "Grain Supply and Demand in China and Its Implications." Paper presented at the International Symposium on Food and Agriculture in China: Perspectives and Policies, October 7–9, Beijing.

———. 1996. "China's Grain Demand and Supply: Trade Implications." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Wu, Y., and H. Yang. 1995. "Growth and Productivity in China's Agriculture: A Review." Working Paper Series 95/2. University of Adelaide, Chinese Economy Research Unit, Adelaide, Australia.

Zhang, L., J. Huang, and S. Rozelle. 1996. "Land Policy and Land Use in China." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

———. 1996. "China's Agro-Environmental Policies and Measures for Sustainable Agriculture." Paper presented at a workshop on Agricultural Policies in China, OECD headquarters, December 12–13, Paris.

Zhu, D. Qu, and Xing Naiquan. 1996. "New Development in Agricultural R&D Policy in China." Paper presented at the China Workshop—Global Agricultural Science Policy for the 21st Century, August 26–28, Melbourne, Australia.

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