CIMMYT Economics Program
Second Distinguished Economist Lecture

How Did China Feed Itself in the Past?
How Will China Feed Itself in the Future?

Justin Yifu Lin

CIMMYT
Sustainable Maize and Wheat Systems for the Poor

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* Professor and Founding Director of the China Center for Economic Research at Peking University, Professor at Hong Kong University of Science and Technology, and Adjunct Professor at the Australian National University.
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Abstract: Feeding China, the world's most populous nation with more than 1.2 billion people, presents challenges and issues that can be instructive for other developing countries, and of consequence to the global community through its impact on world grain stocks and availability. This lecture looks to China's past and current policies to formulate proposals on what steps will be necessary for the country to feed itself in the future. China's past success in reaching food production targets was founded on agricultural research, the adoption of modern technologies, and a farming system based on individual households. Policy changes in the late 1950s precipitated an agricultural crisis not fully alleviated until the rural reforms of 1979. To develop solutions to meet increased food demand created by population and economic growth, the author explores and makes recommendations in four key areas: technological potential for yield improvement; agricultural research for yield improvement; investment in agricultural infrastructure; and incentives for farmers to adopt new technologies, maintain soil fertility, and apply inputs.

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How Did China Feed Itself in the Past?

How Will China Feed Itself in the Future?

JUSTIN YIFU LIN

This lecture poses two questions. The first question—How did China feed itself in the past?—is relevant today for several reasons. China, a developing nation and the world's most populous country, depends on a very limited area of cultivated land. Western observers once referred to China as the "land of famine" (Mallory 1926); today, its ability to feed its people in recent decades is a celebrated achievement in both Chinese and world history. China's experience in achieving self-sufficiency in food production provides extremely useful lessons for other developing countries currently experiencing food shortages.

The second question posed in this lecture—How Will China Feed itself in the Future?—is equally relevant. A small change in China's ability to feed itself in the future could have a large impact on world grain trade and the welfare of poor people in other developing countries.

In 1996, China's population reached 1.2 billion, which was 21% of world population and 38% of the population in low-income economies.¹ However, cultivated area per capita was only around

¹ Unless otherwise indicated, statistical figures in this paper are taken either from various issues of China Statistical Yearbook or A Statistical Survey of China, published by the State Statistical Bureau.
0.1 hectare, a mere 40% of the world average. Moreover, China is one of the driest countries in the world. Water runoff is below the world average, only about one-third of the country’s water resources can be exploited, and annual precipitation is unevenly distributed. The water shortage in the North and Northeast is acute, whereas in the South, floods are a common occurrence. As a result of such poor agricultural endowments and natural conditions, agricultural production failures were frequent before the last several decades of the 20th century.

Throughout the world, more than 800 million people, particularly in developing countries, do no have enough food to meet their basic nutritional needs (Rome Declaration on World Food Security). As we enter the next millennium, we face a greater demand for food than at any time in the past. World population is expected to rise from the current 5.7 billion to 8.9 billion by 2030. How to meet the rising food demand is a great challenge to the international agricultural research centers and national agricultural research systems throughout the world. The story of how the Chinese economy succeeded in feeding its enormous population with such meager agricultural endowments should prove useful to the international community, especially developing countries.

Despite its past success, China’s future ability to feed itself has recently provoked great concern in the international community. The Chinese economy is expected to maintain a dynamic GDP growth rate of 8-10% per year in the coming decades (Lin et al. 1996). Such rapid economic growth is expected to shift China’s comparative advantages away from agriculture (Anderson
1990). Meanwhile, urbanization, expanding markets, and dietary diversification will significantly increase food demand. Moreover, the population may increase another 40%, reaching 1.6 billion in 2030. Because of the sheer size of China’s economy, small changes in the gap between food demand and domestic supply will have large effects on world agricultural trade. Whether China can meet this increasing demand for food in coming decades is an issue of both national and international significance.

This lecture will first examine how China succeeded in feeding its large population in the past. Then I will turn to the second question, considering whether China has the potential to meet future food demand and assessing what measures are required to do so.

**How Did China Feed Itself in the Past?**

For millennia, China has been the most populous nation in the world. Despite the government’s efforts to curb the birth rate, China, like many other developing countries, has experienced rapid population growth in modern times. Between 1952 and 1996, the Chinese population doubled, rising from 575 million to 1.2 billion. Virgin land in China is very limited after thousands of years of continuous cultivation and population expansion. Every increase in population has been accompanied by a corresponding reduction in per capita cultivated area. In the 1950s, per capita cultivated area was already less than half an acre (0.45 acre or 0.18 ha in 1952). Per capita cultivated area dropped to merely one-quarter of an acre in the 1980s (0.1 ha).\(^2\) Despite this reduction in
the agricultural resources available per capita, nutritional intake has improved substantially over past decades (Figure 1). By the 1990s, the per capita daily intake of calories, protein, and fat in China had surpassed the average intake in developing countries and had equaled or exceeded the world average. The Chinese diet is largely based on food grains. According to one estimate, about 90% of the caloric content and 80% of the protein intake in the Chinese diet come from grains (Smil 1981). It is no understatement to say that grain production is the key to China’s food situation.

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Figure 1 A. Per capita daily caloric intake.  
Figure 1 B. Per capita daily protein intake.  
Figure 1 C. Per capita daily fat intake.


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2 For a long time, China’s official figure for cultivated land was 96 million hectares. It is widely believed that the official figure underestimates the actual land area by as much as 30%, and a recent agricultural survey has confirmed this suspicion. The Chinese government may revise the figure to 120 million hectares in the next release of the survey findings.
China changed from being a net grain exporter in the 1950s to a net grain importer for most years after 1960. The net export or net import, however, never exceeded 5% of domestic grain production (Figure 2). China has been virtually a grain self-sufficient economy.

![Figure 2.](image)

Net grain import as percentage of domestic output.


The nutritional intake of the Chinese population improved in the past decades because of increased domestic food production. Grain output tripled from 164 million tons in 1952 to 490 million tons in 1996; as a result, per capita grain availability increased from 285 kg to 400 kg in the same period (Figure 3).

![Figure 3.](image)

Per capita grain output.


Despite the effort to claim new land for agriculture, total cultivated area in China has declined since the
1950s because of competing land use for industrial development, residential construction, and so on. An increase in the cropping intensity index from 130 in 1952 to 158 in 1996 offset part of the decline in cultivated area, but after peaking at 136 million hectares in 1956, area sown to grains declined steadily to 110 million hectares in the 1990s. The increase in grain output is entirely the result of increased grain yields. As shown in Figure 4, grain yield rose in three large jumps during the past four decades, from less than 2 t/ha in the 1950s and 1960s to 2 t/ha in the 1970s, to 3 t/ha in the 1980s, and finally to 4 t/ha in the 1990s. The average annual growth in yields was 2.75% for the 44 years between 1952 and 1996. This gain in yields is one of the most celebrated records in world agricultural history.
In addition to China’s remarkable performance in agriculture, the Chinese economy experienced a dramatic transformation during the same period. Between 1952 and 1996, GDP increased 25 times (Figure 5). Since the late 1970s, the Chinese economy has been the fastest-growing in the world with an average annual growth in GDP of 9.9% from 1978 to 1996. China was predominantly an agrarian economy in the 1950s, but its share of the national economy has dropped from 58% in 1952 to less than 25% in the 1990s.

An important issue confronting most developing countries is how to develop agriculture rapidly, both to meet the increased food demand brought on by explosive population growth and also to support urban industrialization. In this context, China’s achievements have been remarkable. However, along the way China also has made many mistakes, for which it has paid a high
price. These experiences — discussed in greater detail below — can provide many useful lessons for other developing countries.

At the founding of the People’s Republic of China in 1949, 89% of the population resided in rural areas. At that time heavy industry was a major characteristic of the economic structures of developed countries. To enhance national prestige, the government in 1952 adopted a Stalinist development strategy oriented toward heavy industry. The goal was to build, as rapidly as possible, the capacity to produce capital goods and military materials. Agriculture, in effect, was treated as a supporting sector.

Unfortunately, capital was extremely scarce and the voluntary savings rate far too low to finance the high rate of investment in heavy industry sought through this development strategy. To facilitate rapid capital expansion, a policy of low wages for industrial workers evolved alongside the development strategy oriented toward heavy-industry. The assumption was that through low wages, state-owned enterprises would be able to create large profits and reinvest them for infrastructure and capital construction. The practice of establishing low prices for energy, transportation, and other raw materials, such as cotton, was instituted for the same reason.

To implement its low-wage policy, the government needed to provide the urban population with inexpensive food and other necessities, including housing, medical care, and clothing. The government instituted a restrictive food rationing system in 1953,

In addition to grain, rationing included edible oils, pork, and sugar.
which remained in place until the early 1990s. During the same year, to secure a low-priced supply of food for urban rationing, a low-price, compulsory grain procurement policy was imposed in rural areas. The domestic grain trade was virtually monopolized by the state.

The industrial development strategy resulted in greater demand for agricultural products because of the increased numbers of urban workers, the need to expand agricultural exports to earn foreign exchange for importing industrial equipment, and the increased industrial demand for raw material. Under those conditions, agricultural stagnation and poor harvests would not only affect the food supply, but would also have an almost immediate and direct adverse impact on industrial expansion.

Reluctant to divert resources from industry to agriculture, the government pursued a new agricultural development strategy that relied on mass mobilization of rural labor to work on labor-intensive projects, such as irrigation, flood control, and land reclamation, and to raise unit yields in agriculture through traditional methods, such as closer planting, more careful weeding, and the use of more organic fertilizer. The government believed that collectivized agriculture was the farming institution that would make all of this possible.

The traditional farming institution in rural China was the independent family farm. The typical farm was small and fragmented. At the beginning of collectivization, the government promoted a “mutual aid team” system in which four or five
neighboring households pooled their farm tools and draft animals and exchanged their labor on a temporary or permanent basis. The movement was surprisingly successful. It encountered no resistance from farmers and was carried out relatively smoothly. The main rationale of the collective movement was to pursue economies of scale and mobilize rural labor for constructing agricultural infrastructure. The initial success of the program greatly encouraged the government leadership and led to a bolder approach. Farms were enlarged rapidly through successive alterations of the farming institution from mutual aid teams, to primary cooperatives, to advanced cooperatives, and finally to communes in 1958. The communes on average comprised 5,000 farm households and 10,000 workers.

Billions of man-days were mobilized, as expected, but the movement toward communes led to a profound agricultural crisis between 1959 and 1961. The gross value of agriculture, measured at constant 1952 prices, dropped 14% in 1959, 12% in 1960, and another 2.5% in 1961. Most importantly, grain output was reduced 15% in 1959, 16% in 1960, remained at the same low level for another year, and did not return to the 1952 level until 1962. A careful study of recently released demographic data indicates that this crisis resulted in about 30 million additional deaths and approximately 33 million lost or postponed births from 1959 to 1961 (Aston et al. 1984).

4 There have been many attempts to explain this crisis. The conventional hypotheses for the sudden reduction in grain output were three successive years of bad weather, poor policies and poor management in the communal movement, and incentive problems resulting from the unwieldy size of the communes. Lin (1990) found that empirical data do not support these conventional hypotheses and proposed that the main cause of the agricultural collapse was the loss of the peasants' right to withdraw from the collectives. This switch in the form of organization changed the incentive structure for the peasants and consequently undermined agricultural productivity (see further discussion later in this section). Lin and Yang (1997) also found that an urban bias in grain distribution during the famine year was a much more powerful explanation of cross-sectional differences in the death rate during the famine than food availability.
Although the government did not abolish the communes after the crisis, it did delegate agricultural operations and management to a much smaller unit, the “production team,” consisting of 20-30 neighboring households. This system remained the basic farming institution from 1962 until 1979 when rural reform replaced the production team system with a household-based farming system, called the “household responsibility system.”

The 1959-61 crisis made the government more realistic and for a number of years immediately afterward the government gave priority to agriculture in its development strategy. Government policy started to emphasize modern inputs. China’s irrigated area increased gradually from 30.55 million hectares (29.7% percent of cultivated area) in 1962 to 44.97 million hectares (45.2% percent of cultivated area) in 1978, but as Table 1 shows, most of this increase

<table>
<thead>
<tr>
<th>Year</th>
<th>Total irrigated area (M ha)</th>
<th>Irrigated area in total cultivated area (%)</th>
<th>Tractor-plowed area</th>
<th>Chemical fertilizer</th>
<th>Electrical use (M kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>19.96</td>
<td>18.5</td>
<td>0.14</td>
<td>0.08</td>
<td>50</td>
</tr>
<tr>
<td>1957</td>
<td>27.34</td>
<td>24.4</td>
<td>2.64</td>
<td>0.37</td>
<td>140</td>
</tr>
<tr>
<td>1962</td>
<td>30.55</td>
<td>29.7</td>
<td>8.28</td>
<td>0.63</td>
<td>1,610</td>
</tr>
<tr>
<td>1965</td>
<td>33.06</td>
<td>31.5</td>
<td>15.58</td>
<td>1.94</td>
<td>3,710</td>
</tr>
<tr>
<td>1978</td>
<td>44.97</td>
<td>45.2</td>
<td>40.67</td>
<td>8.84</td>
<td>25,310</td>
</tr>
<tr>
<td>1984</td>
<td>44.64</td>
<td>46.1</td>
<td>34.91</td>
<td>17.40</td>
<td>46,400</td>
</tr>
<tr>
<td>1995</td>
<td>49.28</td>
<td>51.9</td>
<td>65.6</td>
<td>35.94</td>
<td>71,200</td>
</tr>
</tbody>
</table>

came from the spread of powered irrigation rather than the construction of labor-intensive canals and dams. The utilization of chemical fertilizer accelerated as well, rising from a very modest 4.6 kg/ha in 1962 to 58.9 kg/ha in 1978. Equally impressive was the expansion in the utilization of electricity, a 17.5-fold increase between 1962 and 1978.

However, the most noteworthy change was the establishment of an agricultural research and extension system for modern varieties. As a matter of fact, agricultural research is an area that the Chinese government can view with pride. The Chinese Academy of Agricultural Sciences was founded in Beijing in 1957; concurrently, each of the 29 provinces in the mainland established its own academy of agricultural sciences. Each national and provincial academy consists of several independent research institutes. Most prefectures also founded prefectural research institutes. In addition, agricultural research was conducted in a few research institutes of the Chinese Academy of Sciences and in some universities.

This agricultural research system was disrupted during the Cultural Revolution, from 1966 to 1976. The Chinese Academy of Agricultural Sciences and many provincial and prefectural academies were reorganized, and many research scientists were sent in small groups to work on farms. The agricultural research system was restored after the end of the Cultural Revolution, and at that time many counties also established their own agricultural research institutes. The agricultural research institutes were funded by government budgets at their corresponding levels. The
Ministry of Agriculture and the State Science and Technology Commission, however, also provided grants to research projects at lower level institutes.

The division of labor among the various levels of research institutes (national, provincial, prefectural, and county) was rather broad, and there was some overlap. The research institutes in the Chinese Academy of Agricultural Sciences emphasized basic and applied research with national significance. They were also responsible for technical supervision and coordination of provincial programs. The institutes in provincial academies stressed applied research in accordance with the ecological conditions of each province. Prefectural institutes mainly engaged in selection and adaptive research. County research institutes were primarily responsible for extension work. Each institute set its own research agenda under the supervision of its corresponding level of government and institutes at higher levels. In addition, the Ministry of Agriculture and the State Science and Technology Commission also initiated some centrally orchestrated, nationwide research programs on specific crops and problems.

Variety improvement has been the core of China's agricultural research program from the very beginning. In the early 1950s, emphasis was given to the selection and promotion of the best local varieties. New varieties of rice, wheat, cotton, maize, and other crops were also imported from abroad. A major breakthrough in rice breeding occurred in 1964 when China began full-scale distribution of fertilizer-responsive, lodging-resistant
dwarf rice varieties with high yield potential. This breakthrough occurred two years earlier than IRRI's release of IR-8, the variety that launched the Green Revolution in rice elsewhere in Asia. At about the same time, hybrid maize and sorghum, improved cotton varieties, and new varieties of other crops were also released and promoted. These high yielding varieties were rapidly adopted.

A second major breakthrough in rice breeding occurred in 1976, when China became the first country to commercialize the production of hybrid rice. The innovative breeding and commercial development of hybrid rice has been heralded by some as the most important achievement in rice breeding in the 1970s (see Barker and Herdt 1985: 61). By 1979, high yielding varieties covered 80% of the rice area, 85% of the wheat area, 60% of the soybean area, 75% of the cotton area, 70% of the peanut area, and 45% of the rapeseed area (Ministry of Agriculture, Planning Bureau, 1989: 248-249).

The centrally planned economic system characteristic of socialist economies is known for its ability to mobilize resources for specific projects. The national, concerted effort to develop and commercialize hybrid rice is a good example of this capability. However, the decentralized research system described previously

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5 Rice is a self-pollinating plant. For commercial hybrid rice production, it is necessary to have a genotype that is male sterile (a rare genetic characteristic), cross it with "maintainer lines" to produce offspring with male sterility and other desirable characteristics, and then cross the progeny again with "restorer lines" to produce seed with normal self-fertilizing capability. The first male-sterile variety was discovered in 1970 by Yuan Longping, a dedicated breeder at a high school, and his assistant. In 1971, the search for "maintainer lines" and "restorer lines" became a concerted nationwide program that involved more than 20 research institutes in several provinces. The first maintainer variety was discovered by Yuan and another researcher in Jiangxi Province in 1972, and the first restorer variety was discovered by a breeder in Guangxi Province in 1973. A hybrid combination with marked heterosis was bred in 1974. Regional production tests were conducted simultaneously in hundreds of counties in 1975. In 1976, hybrid rice began to be commercially released to farmers.
also followed underlying economic principles to a remarkable extent. Theories of technological innovation in a market economy state that the allocation of resources should reflect the market size of the technology (Griliches 1957; Schmookler 1966) and the scarcity of the factor that the technology is replacing (Hayami and Ruttan 1970). Lin (1991a) has argued that theoretically the principles for effective technological innovation in an economy without markets are the same as in a market economy. Lin (1991b, 1992a) also empirically found that the pattern of research resource allocation in a research institute and farmers' adoption of new technology in a locality could be well explained by the market size and factor scarcity in that locality.

Research efforts and the application of new technologies are expected to contribute significantly to growth in agricultural output. The yield profile in Figure 4, which measures changes in land productivity, provides indirect evidence of the contribution of research and technologies to grain production. In an empirical study that directly measured the contribution of research to production, Fan and Pardey (1997) found that 20% of the growth in agricultural output from 1965 to 1993 was attributable to research-induced technological change. Another empirical study, focused on rice production from 1970-90, also confirmed the primacy of technological change in explaining yield improvements (Huang and Rozelle 1996). However, when we look at total factor productivity (TFP) instead of land productivity and examine the productivity profile for the entire period from 1952 to 1996 (instead of just a subperiod), we see a quite different picture. Studies by Fan (1997) and Wen (1993) show that the TFP
throughout the 1960s and 1970s was lower than that in the 1950s and did not rise above the 1952 level until the beginning of the agricultural reform in 1979. (For reference, Fan’s estimate of TFP in 1952-95 is reproduced in Figure 6.)

Figure 6.
Total factor productivity in agriculture.

Two puzzling findings may be observed in Figure 6. First, modern technologies, such as high yielding varieties, chemical fertilizers, and the more reliable powered-irrigation system, would be expected to improve agricultural productivity. Why then, in spite of the widespread adoption of modern varieties and the intensive use of modern inputs in the 1960s and 1970s, was TFP even lower than in 1952, when modern technologies were not yet available or only rarely used? The second puzzle relates to the pattern of increases in TFP. Why did TFP increase between 1952 and 1958, when the household system was replaced by collective farming, and why did TFP increase yet again in the period after
1979, when the collective system was replaced by the household system?

As described previously, when China adopted the heavy-industry oriented development strategy in the early 1950s, the government simultaneously promoted collectivization as a strategy for agricultural development. Because of the temporal and spatial dimensions and biological nature of agricultural production, effective supervision of labor in an agricultural collective is very costly (Lin 1988). The success of an agricultural collective depends inescapably on a tacit promise of self-discipline established by members of the collective. However, a self-enforcing agreement can be sustained only if members of the collective have the right to quit the collective when the other members do not honor their promises (Telser 1980).

At the beginning of the collective movement, the government actively encouraged farmers to join collectives but also followed the principle of voluntarism, allowing individual farmers to quit a collective if it failed to meet their expectations. Consequently, the self-enforcing agreements in most collectives were sustained, and overall agricultural performance improved because of the economies of scale in the collectives. However, there was an inherent danger in the initial success of collectivization. As a result of differences in their time preferences, abilities, and other endowments, some members of a collective might take advantage of low supervision and attempt to evade the responsibilities stipulated in their self-enforcing agreement. As a result, the disintegration of some collectives was inevitable,
even though the overall performance of the movement was successful. The collapse of some collectives in itself was an effective discipline mechanism (Holmstrom 1982). It made a potential violator of the self-enforcing agreement realize that honoring the agreement was to his or her advantage.

Encouraged by the initial success of the movement, however, zealous political leaders of a collectivization movement might have interpreted some individual members' exit from the collectives in a different way. These individuals were viewed as enemies of the movement. To prevent the collapse of other collectives, compulsory measures were taken. Collectivization thus changed from a voluntary to a compulsory movement and the safety valve was removed. In a compulsory collective, the incentive to work depends on the effectiveness of supervision (Lin 1988). Because the supervision of production in an agricultural collective is too costly to be effective, the incentive for farmers to work is low and agricultural productivity is depressed to a level lower than in individual household farming.

The change from a voluntary collective movement to a compulsory one occurred in 1958, with the government's push to replace the advanced cooperatives with gigantic communes. Lin (1992b) estimated that productivity was about 20% lower in a compulsory agricultural collective than in a household farm. Studies by McMillan et al. (1989), Fan (1991), and Huang and Rozelle (1996) reinforce Lin's finding. Therefore, despite the favorable impact of modern technologies, TFP was lower in the 1960s and 1970s than in the 1950s. TFP increased in the 1952-58
period because the exit right was respected during that time. TFP also increased after 1979 because the farming institution changed from a compulsory collective system to the individual household system.

**How Will China Feed Itself in the Future?**

Although China’s ability to feed itself during the last 45 years was highly acclaimed, really remarkable achievements in Chinese agriculture did not occur until the reform began in 1979 (Table 2). Major elements of the reform included the replacement of the collective team system with the household responsibility system, the expansion of rural product and factor markets, and the liberalization of agricultural prices, except for grain and cotton (Lin 1997a). Among those reforms, the change to the household system had the largest impact on productivity (Lin 1992). Between 1979, when this institutional change began, and 1984, when it was complete, we see the largest annual growth rate in agriculture’s TFP as well as in total grain output and per capita

<table>
<thead>
<tr>
<th>Period</th>
<th>Agricultural TFP</th>
<th>Grain Total</th>
<th>Per Capita</th>
<th>Grain</th>
<th>Consumption level index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952-96</td>
<td>1.51</td>
<td>2.52</td>
<td>0.77</td>
<td>7.7</td>
<td>4.5</td>
</tr>
<tr>
<td>1952-78</td>
<td>-0.25</td>
<td>2.41</td>
<td>0.40</td>
<td>6.1</td>
<td>2.2</td>
</tr>
<tr>
<td>1978-84</td>
<td>5.10</td>
<td>4.95</td>
<td>3.70</td>
<td>9.3</td>
<td>7.7</td>
</tr>
<tr>
<td>1984-96</td>
<td>3.91</td>
<td>1.55</td>
<td>0.14</td>
<td>10.2</td>
<td>8.1</td>
</tr>
</tbody>
</table>

Note: TFP figures are for the period of 1952-95. Source: TFP figures from Fan (1997); other figures from various issues of *China Statistical Yearbook*. 

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grain output (Table 2). However, the impact of this institutional change on agricultural production was a one-time effect that had run its course by 1984. Although growth since 1984 in TFP has remained substantially higher than in the pre-reform period, annual growth of grain output has declined significantly. The average annual growth rate of 1.55% from 1984-96 was even lower than the average annual growth rate of 2.41% in the pre-reform period of 1952-78. As a result, during 1984-96, the annual growth rate of grain output per capita was 0.14%, the lowest since 1952. The poor performance in grain production resulted mainly from continuous government intervention in grain production and marketing. As the government liberalized the prices and marketing of most other agricultural products, the production of grain became less profitable than other products and farmers did not have adequate incentives to increase grain output (Lin and Li 1995).

The rural reform is a part of China's overall reform. The success of the household responsibility system from 1978-84 encouraged the Chinese government to take bolder measures in reforming the overall economy. As a result, annual growth in GDP rose from 9.3% during 1978-84 to 10.2% from 1984-96. Nationwide, the level of consumption, particularly of the urban population, accelerated correspondingly (Table 2).

When the reform was initiated in 1978, the government adopted a gradual, incremental approach that was very effective in maintaining social stability and stimulating economic growth (Lin et al. 1996a). This approach inherently poses a number of
issues for the economic system (Lin 1997b), nevertheless, the Chinese economy is expected to maintain its dynamism for several decades to come. The forces that drive economic growth in an economy are capital accumulation, improvements in resource allocation, and technological change. China has one of the highest savings rates in the world, reaching 35% of GDP per year. In the transition from a planned economy to a market economy, the potential for improving resource allocation is great. Even more important is the role of technology. The current technological level in China is very low, but this seeming disadvantage actually means that there is considerable potential for catching up technologically, at a low cost. China’s GDP is likely to maintain an annual growth rate of close to 10% for another two or three decades (Lin et al. 1996a).

Currently China’s per capita nutritional intake surpasses the world average, but still falls short of the standards of developed countries. Consumption of animal products is substantially lower (see Table 3). Certainly, the share of animal products in a person’s

<table>
<thead>
<tr>
<th>Item</th>
<th>China</th>
<th>Developed countries</th>
<th>Hong Kong</th>
<th>Korea</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (Kcal)</td>
<td>2,741 506</td>
<td>3,191 861</td>
<td>3,285 1,048</td>
<td>3,268 511</td>
<td>2,887 596</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>72 24</td>
<td>98 55</td>
<td>109 78</td>
<td>85 35</td>
<td>96 53</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>69 44</td>
<td>114 63</td>
<td>137 72</td>
<td>82 38</td>
<td>80 36</td>
</tr>
</tbody>
</table>

Source: FAO, FAOSTAT.
daily diet is determined by many economic and noneconomic factors aside from income level. However, based on the experiences in Hong Kong, Korea, and Japan, when China's income increases, the demand for animal products will increase proportionally. This implies that, although per capita direct consumption of grain may decline as incomes rise, the increase in indirect demand through consumption of animal products will outweigh the decline in direct consumption demand.

In addition, the demand for grain will increase as the population grows. The current population of 1.22 billion may grow by 30-40% by 2030. Thus even if the current consumption level is maintained, China's grain demand will rise substantially.

As income and population grow, however, cultivated area will decline with the construction of houses, roads, factories, and other facilities. Since 1988, 190,000 ha of farmland have been diverted each year for these purposes. Environmental degradation may further reduce the land available for cultivation. New land can be claimed for farming, but its quality and productivity are poor (World Bank 1997: 66).

Income growth will also stimulate demand for vegetables and fruits, which will compete with grain for limited agricultural land. Area sown to grain declined from 80.3% percent of total cultivated area in 1978 to 73.8% in 1996, while the area sown to vegetables and fruits increased from 2.5% percent to 7.7% (Figure 7). Similarly, the demand for freshwater fish will also reduce the land area available to produce grain and other crops.
As incomes grow, China's comparative advantages will also change. Not only land but also labor, water, and other resources will be shifted away from the production of grain to other more profitable agricultural and nonagricultural products.

Many recent studies have examined China's future grain demand and supply (Brown 1995; Garnaut and Ma 1992; Huang et al. 1997; World Bank 1997). Most studies differ little with respect to their projections of China's grain demand because their assumptions about population and income growth are similar. However, their projections of grain supply differ greatly, leading to confusing estimates of the magnitude of China's future demand for grain imports.

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6 For a review of these studies, see Fan and Agcaolli-Sombilla (1997).

7 Brown estimates that China will require 207-369 million tons of grain imports in 2030, which he thinks will drain world supplies, force grain prices up, and deny other low-income countries access to the world grain market. However, his prediction is based on a misinterpretation of data and erroneous assumptions. Brown's projection aroused much public concern and awareness of these issues in China and throughout the world. His study, nevertheless, cannot sustain academic examination and can thus be disregarded (Alexandratos 1996).
Leaving the issue of demand aside, the magnitude of China's future grain imports depends on how much grain China can and will produce domestically, which in turn depends on four factors: (1) the technological potential for further improvement in yield; (2) government investments in research and extension to develop technologies that can tap yield potential; (3) investments in infrastructure to maintain soil fertility and improve irrigation systems; and (4) farmers' incentives to adopt new technologies and maintain soil fertility. I will discuss each of these factors in the sections that follow.

Technological Potential for Yield Improvement

Figure 8 shows the 1995-97 average yields of rice, wheat, and maize in China, the world average, the country with the highest yield in the world, and the highest experimental yield that has ever been obtained in China on an area larger than 0.1 ha.8

Of China's three major grain crops, rice has the highest yield. Rice is also the only grain crop in China whose yields approach the highest yields in the world. In 1995-97, China's average rice yield was 6.2 t/ha, 63% higher than the world average of 3.8 t/ha and only 25% lower than the highest yield of 8.3 t/ha, achieved in Puerto Rico. However, actual rice yields in China were only about 35% of the highest yields obtained in experimental fields in China.

Wheat, on the other hand, has the lowest yield of the three major grain crops in China, a pattern similar to that for the world as

8 Figures for average yields in 1995-97 are obtained from FAO's FAOSTAT. The highest experimental yields are taken from Lin et al. (1996b).
Figure 8 A. Rice yield.
[Graph showing rice yield for China, World Average, Puerto Rico, and Highest Exp. yield.]

Figure 8 B. Wheat yield.
[Graph showing wheat yield for China, World Average, Netherlands, and Highest Exp. yield.]

Figure 8 C. Corn yield.
[Graph showing corn yield for China, World Average, United Arab Emirates, and Highest Exp. yield.]


a whole. The wheat yield in China in 1995-97 was only 3.7 t/ha, 48% higher than the world average of 2.5 t/ha, but 57% lower than Netherlands' 8.7 t/ha. The highest experimental yield ever recorded in China was 13.2 t/ha. The gap between the actual yield and the highest experimental yield is 9.5 t/ha, or 257% of the current yield level.

China's maize yield in 1995-97 was 4.9 t/ha, only 22.5% higher than the world average of 4.0 t/ha and just 26% of the highest yield of 18.8 t/ha, achieved in the United Arab Emirates. The highest experimental yield ever observed in China was 19.1 t/ha, only slightly higher than the actual yield in the United Arab Emirates.
The gaps between China’s actual grain yields and the world’s highest grain yields, and between China’s actual yields and its highest experimental yields, are two different measures of the potential for yield improvement. From these measures, we can conclude that there are still great possibilities for yield improvement in China.

A large portion of the gap between actual yields on the farm and the highest yields on the experimental plots or in the world can be attributed to technical constraints. Table 4 reports results of a 1992 survey of more than 2,000 agronomists and plant breeders in China. The researchers were asked which technical constraints contributed to the gap between actual yields and the highest potential yields for the three major grain crops. Technical constraints were found to account for 8 t of the difference between actual and highest experimental yields for rice, 9 t for wheat, and 11.5 t for maize. Differences in crop characteristics, such as plant architecture,

<table>
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<tr>
<th>Table 4. Technical constraints to improved grain yield; China.</th>
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<tr>
<td>Yield gap resulting from technical constraints (t/ha)</td>
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<tr>
<td>Rice</td>
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<tr>
<td>-------</td>
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<tr>
<td>8.0</td>
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<tr>
<td>Contributing factors (%)</td>
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<tr>
<td>1. Crop characteristics</td>
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<tr>
<td>100.0</td>
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<td>2. Environmental conditions</td>
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<tr>
<td>52.0</td>
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<td>3. Soil conditions</td>
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<tr>
<td>32.1</td>
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<tr>
<td>4. Pests, diseases, weeds</td>
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<tr>
<td>7.4</td>
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<tr>
<td>5. Weather conditions</td>
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<tr>
<td>6.3</td>
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</table>

Source: Lin et al. (1996b).

9 Not all yield differences are caused by technical factors. Socioeconomic factors, such as the purity of seed and the timing of fertilizer and water applications can also contribute to the differences between actual and experimental yields.
photosynthetic efficiency, time to maturity, and so on, had the largest impact, accounting for about half of the yield differences due to technical constraints for all three crops. Differences in environmental conditions had the second most important impact on yield between experimental fields and average farmers' fields; factors included radiation, accumulated temperature, and humidity. Environmental conditions accounted for about one-third of the yield differences from technical factors. Soil conditions, weather conditions, pests, diseases, and weeds accounted for the rest of the yield differences (Lin, et al. 1996b). Potentially, technical constraints can be overcome by breeding varieties with desired traits and developing other new technologies. These are the directions that yield improvement research should take.

**Government Investments in Agricultural Research**

Since 1961, the number of research personnel in China's agricultural research system has increased by 7.3% annually; real research expenditure increased by 5.7% per year. China now has the largest team of agricultural research personnel in the developing world.\(^{10}\) China's agricultural research intensity (ARI), a measure of agricultural research investment relative to agricultural GDP, in the early 1960s was 0.41, much higher than the developing country average of 0.24 in the same period. From the 1960s to the 1980s, the ARI was maintained at the same level (Fan and Pardey 1997). Such efforts made China the world leader in many areas of grain research in the 1960s and 1970s. However, looking ahead we can see several alarming signs in China’s agricultural research system.

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\(^{10}\) It should be noted that only 5-6% of the researchers in China hold a postgraduate degree, whereas in the national systems of other less developed countries the proportion is 60-70% (Fan and Pardey 1997).
As part of the overall market-oriented reform, there has been a reform in agricultural research funding policy in the 1990s. The government reduced its fiscal appropriation for agricultural research, shifted funding from institutional supports to competitive grants, and encouraged research institutes to commercialize their technologies, using part of the proceeds to subsidize their research. The research institutes' real income from technology commercialization increased substantially. However, the proportion of that income that was used to subsidize research was far from sufficient to compensate for the reduction in fiscal appropriation (Scott et al. 1997). As a result, the ARI declined to 0.34 in the 1990s (Huang 1997). New technologies for agricultural research, such as genetic engineering, require a heavy investment in research. The reduction in research funding will hurt China's agricultural research capacity in the long run.

China's agricultural research system has another serious problem: the lack of appropriate compensation for scientists. A highly qualified plant breeder earns approximately the same salary as an unskilled manual worker. This compensation system deters promising young students from pursuing advanced studies in agricultural sciences and discourages many talented agricultural scientists who have been trained abroad from returning to work in China. As the Chinese economy moves towards a market system, this deterrent will become more and more serious. It is noteworthy that the agricultural research system has been losing staff since the mid-1980s. In 1986, the total number of agricultural scientists in the

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11 China's ARI in the 1980s was already one-quarter lower than the average of developing countries because of substantial increases in those countries, especially in Asia (Fan and Pardey 1997).
national system, excluding those in the universities, was 232,683. This number dropped 15% to 196,708 in 1996.¹²

**Investments in Agricultural Infrastructure**

As China’s population increases, the amount of land and water available for agriculture will become increasingly scarce in per capita terms. Population pressure may also lead to growing environmental degradation, including erosion and salinization, and may reduce the amount of land suitable for cultivation. The breeding of higher yielding varieties and varieties resistant to environmental stresses may compensate for the decline in cultivated land. However, it is also important to protect the resource base through measures to control erosion, control water, and enhance soil fertility. In the pre-reform period, the government was able to mobilize agricultural labor in slack seasons for environmental improvement projects such as upgrading irrigation systems, salinization control, reforestation, and terracing. Since the shift to the individual household farming system, it has become more difficult to mobilize rural labor for such projects. Government investment in projects for upgrading or maintaining the agricultural resource base thus becomes increasingly important.

When the reform started at the end of 1978, the government made a commitment to increase fiscal expenditure on agriculture from 13% of the budget to 18% in subsequent years. Although the expenditure on agriculture did increase for one year, it declined sharply after 1980 following the success of rural reforms in bringing

¹²*The number of research scientists was provided by Jikun Huang.*
out strong agricultural growth (Figure 9). Budgetary expenditures for agricultural infrastructure show a similar pattern. After 1985, because of the stagnation in grain production, the government’s fiscal expenditure on agriculture recovered somewhat but declined again in the 1990s when growth in grain output resumed. The right-hand panel of Figure 9 shows that

![Figure 9 A. Agricultural expenditures in government budget.](image)

![Figure 9 B. Real agricultural infrastructural investment.](image)

Source: State Statistical Bureau, various issues.

government expenditures on investment in agricultural infrastructure projects, measured in 1978 constant prices, fell from their peak in 1979 to about half of that level afterwards.

The ability of Chinese agriculture to resist flood, drought, and other unfavorable weather conditions has declined, probably because of increased environmental stress arising from population
pressure and economic activity, and the reduction in infrastructure investments. Figure 10 shows the percentage of cultivated area hit by natural disasters resulting in yield reductions of 30% or more compared to a normal year. It is clear that this trend has been increasing since the 1970s. Without substantial government investments in agricultural infrastructure to offset environmental stresses arising from population pressure and intensification of economic activities, the agricultural system’s ability to withstand unfavorable weather conditions will decline; hence the prospects for stable and sustained improvement in yields and output growth will be jeopardized.

**Figure 10.** Percentage of sown area affected by disasters.

Sources: Ministry of Agriculture, Planning Bureau (1989) and State Statistical Bureau, various issues.

Farmers’ Incentives to Adopt New Technologies, Maintain Soil Fertility, and Apply Inputs

New technologies promise to increase grain output by raising yields instead of expanding cultivated area. However, new technologies will work only if farmers adopt them. The adoption of new technologies is an economic decision. In a market economy, farmer adoption of a new technology depends on the costs and benefits of adopting it. The costs of adoption are determined predominantly by the availability of extension services and a seed production and distribution system. The benefits of adopting new technologies depend on the magnitude...
of the yield increase or cost reduction and the level of the output price. After shifting to the household farming system, Chinese farmers have become more sensitive to the costs and benefits of technology adoption (Lin 1991c).

Before the reform, the administrative network was quite effective in extending new technologies and making them available to farmers. There is evidence that this extension network has been disrupted since the shift to the household farming system; a development that will have an adverse effect on the costs of adopting new technologies (Lin 1991c). Moreover, although the government has liberalized most markets, it still controls the domestic grain trade. Currently the government purchases about three-quarters of all marketed grain (World Bank 1997). The government’s procurement prices will have a large effect on the profitability of using new technologies. The government’s predominant concern is the welfare of urban consumers, so it has often kept procurement prices well below market prices, raising them only when problems with the domestic grain supply threatened food security. To increase farmers’ incentives for adopting new technologies, the government needs to strengthen the extension network and liberalize the grain pricing system, making production of grain as profitable as production of other crops.

Given that most farmland in China has been cultivated continuously for thousands of years, it is remarkable that soil fertility has not declined. The wide application of organic fertilizers and the use of green manures have helped maintain soil
fertility; such measures are a type of long-term investment.
Farmers will have incentives to adopt those measures only when
their long-term returns are secure. When the household
responsibility system was first adopted in the late 1970s and early
1980s, collective land was leased to individual households for one
to three years, a period that was too short for farmers to recoup
investments in soil fertility maintenance and other long-term
investments. In response to this concern, the government
subsequently allowed contracts to be extended to 15 years and
then to 30 years. However, frequent redistribution and
reallocation of land among households in a village is common in
many areas. To increase the incentives for maintaining soil fertility
and investing in activities that enhance soil fertility, the
government needs to adopt effective policy measures to assure
that farmers’ land tenancy contracts are secure.

An issue similar to the land tenure/land quality issue is how
to maintain water resources and water use rights. Water is even
scarcer than land for agricultural production in China, but water
use is currently very wasteful. Most irrigation and drainage
systems are old and poorly maintained because of inadequate
budgets and fragmented responsibilities across levels of
government. Water charges are too low. On the one hand, low
charges reduce farmers’ incentives to conserve water in
production; on the other, the charges are not sufficient to cover
maintenance costs, reducing the government’s incentive to invest
in and maintain the irrigation system. To improve the incentives
for farmers to conserve water and for the government to make
public investments, it is necessary to reform the present policy
that keeps water charges low. Prices should be raised to a level at which investments in irrigation projects generate appropriate returns and are sufficient to maintain the systems.

Conclusion

In the past, the keys to China's success in feeding its large population were agricultural research, modern technologies, and a farming system based on the individual household. Formerly, when flagging grain production threatened food security, the government adjusted its policies and provided the agricultural sector with appropriate supports.

The Chinese government is still committed to a policy of producing enough grain domestically to meet its food needs in the future (Huang 1997b). There is considerable technical potential to achieve this goal, but some policy reforms are required to tap that potential. China will not have a grain problem so much as a series of policy problems as noted by Johnson (1994). We have reasons to be optimistic about such reforms and China's ability to meet domestic grain demand in the future.

If in the future the government abandons its policy of self-sufficiency in grain production, this does not mean that China will lose the ability to feed itself. Just the opposite! With trade liberalization, China is likely to export more labor-intensive, high value-added foodstuffs, in addition to labor-intensive manufactured products. In value terms, China will be a net exporter of food (Lu 1996). Moreover, the improvement in
resource allocation arising from trade liberalization will increase incomes and household budgets for food expenditures, with the result that the Chinese people will feed themselves even better than before.

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References


