Stanford
Center for International Development

Working Paper No. 56

What Will Make Chinese Agriculture More Productive?

by

Jikun Huang

Justin Y. Lin**

Scott Rozelle***

August, 2000

Stanford University
John A. and Cynthia Fry Gunn Building
366 Galvez Street | Stanford, CA | 94305-6015

---

* Professor Jikun Huang, Center for Chinese Agricultural Policy, Chinese Academy of Agricultural Sciences

** Professor Justin Y. Lin, China Centre for Economic Research (CCER) at Peking University, China, and Hong Kong University of Science and Technology

*** Professor Scott Rozelle, Department of Economics, University of California, Davis

What Will Make Chinese Agriculture More Productive?

Jikun Huang
Center for Chinese Agricultural Policy
Chinese Academy of Agricultural Sciences

Justin Y. Lin
China's Center for Economic Research
Peking University

and

Scott Rozelle
University of California, Davis

A paper presented at a Conference on Policy Reform in China, 18-20 November 1999, Stanford University.

We would like to thank Nick Hope, Songqing Jin, D. Gale Johnson, Thomas Rawski, Dennis Yang, Linxiu Zhang and an anonymous referee for reading and providing comments on earlier versions of this (document) paper.

Abstract

This paper reviews China's development strategies in agriculture, the reforms that it has pursued in the past for achieving its current level of food security, raising agricultural productivity and augmenting farm income. It evaluates the effects that these strategies and reforms have had on agricultural production, with emphasis on the role of technology innovation and adoption. Finally, we seek to identify constraints and challenges that China will face and to analyze the scope for further agricultural and rural reforms. In particular, three scenarios with different underlying assumptions of technology investment and trade liberalization are presented to highlight the potential impact on grain self-sufficiency.

I. Introduction

The international community has long recognized China's effort to produce enough food to feed its growing population. Tremendous progress has been achieved in agricultural productivity growth, farmer's income, and poverty alleviation during the reform period. China's experience demonstrates the importance of institutional change, technological development, price and market liberalization, and rural development in improving food security and agricultural productivity in a nation with limited land and other natural resources (Lin, 1998).

Policies successful in the past, however, do not guarantee future agricultural production growth. While most recent studies have led to a consensus that the increases in China's grain imports will not starve the world, China still faces an enormous challenge to supply its growing population with high-quality, reasonably-priced food and steadily raise rural income in the next millennium (World Bank, 1997). Agricultural productivity growth will determine whether China has the ability to feed itself in the future because rapid industrialization and urbanization will lead to competition for resources between agricultural and non-agricultural sectors.

Several key questions arise for policymakers when they address the challenge of how to sustain agriculture's productivity growth, achieve food security, and increase farm incomes, especially given the fact that China will almost certainly be faced with the process of agricultural trade liberalization (Huang and Chen, 1999; Cheng, 1998). What are the sources of agriculture growth in China in the future? What are the major constraints and challenges that China's agriculture will face? What is the importance of the role of technology, given its past contribution? How will trade liberalization affect China's agricultural production and the national food security? What are the policy implications of the changes in the economy that will result from the trade liberalization? In general, how can China formulate effective policies to achieve sustainable growth of agriculture supply and productivity in the decades ahead?

The overall goal of this paper is to begin to provide some answers for these questions, answers that are complicated, especially given the fact that China is undergoing a number of radical changes: transition from a planned to a market economy, global integration, urbanization, shift of comparative advantage from agriculture to other sectors, and diversification of diet. To meet this overall goal, we direct our attention at a more circumscribed set of objectives. Our paper reviews China's development strategies and the reforms that it has pursued in the past for achieving its current level of food security, a central goal of China's agricultural policy, and for raising agricultural productivity and farm income. Next, we evaluate the effects that the strategies and reforms have had on agricultural production. Finally, we seek to identify constraints and challenges that China will face and to analyze the scope for further agricultural and rural reforms.

While we are interested in farm-sector productivity and rural incomes, in general, most of this article focuses on a narrower set of issues, especially the role of technology in China's food economy. Rural development in China is a complicated process and will require good policies beyond the way the government must manage agriculture technology. Issues of land management, fiscal and financial policy, and many other issues are equally as important. In fact, in a recent conference on land tenure in Beijing, D. Gale Johnson convincingly argued that land reform is critical in promoting economic modernization of both the rural farm and non-farm sectors. We agree. Unfortunately, space limitations preclude us from giving more emphasis to these issues in this paper.

II. Agricultural Development in the Reform Economy

Role of Agriculture in the Economy

Since China's leadership initiated the economic reforms in 1978, the economy has grown steadily. The annual growth rate of China's GDP averaged approximately 9.5 percent between 1979 and 1995 (Table 1). China's foreign trade has expanded even more rapidly than its overall economic growth, except during the most recent three-year period. Even when the Asian financial crisis plagued the region in the late 1990s, China's economy continued to grow, albeit at a somewhat more moderate rate than during the pre-crisis period.[1] China's GDP grew at 7.8 percent in 1998 and 8.3 percent in the first quarter of 1999 (compared to the first quarter of 1998). From a technological point of view, China's economy has the potential to maintain a dynamic GDP growth rate of 8 to10 percent annually in the coming decades (Lin, Shen, and Zhao, 1996).

Successive transformations of China's reform economy have been rooted on dynamic growth in the agricultural sector. However, agriculture's contribution to national economic development in terms of gross value added, employment, capital accumulation, urban welfare, and foreign exchange earnings has been declining. Agriculture contributed 40 percent of GDP in 1970, but fell below 20 percent in the mid-1990s (Table 2). Agriculture employed 81 percent of labor in 1970, but only 50 percent in 1998. Within the agricultural sector, cropping is the dominant activity, contributing 82 percent of the gross value of agricultural output in 1970. By 1998, however, its share fell to only 56 percent. The shares of livestock and aquatic output more than doubled during the same period (Table 2).

The declining role of agriculture in international trade is particularly striking. The share of primary (mainly agricultural) products in total exports was 50 percent in 1980 (Table 2). By the mid-1990s, the share was less than 15 percent. The share of food exports to total exports fell from 17 percent in 1980 to only 6 percent in 1998. Food imports fell from 15 percent to 3 percent in the same period.

The declining importance of agriculture, particular the cropping sub-sector, in the economy is historically common to all developing economies. Since China is densely populated and its average farm size is less than 0.5 hectare, population growth and limited land resources should be expected to shift China's comparative advantage from land intensive

[1] The crisis has not directly spread to China, in part a consequence of the more insulated nature of its economy, in part due to the size of its domestic capital market, and the strength of its domestic demand that allowed China to better weather the international financial crisis. However, China has not been totally immune to the recent financial crisis in Asia, given China's dependence on trade with Asia. The growth rate of China's export value declined to almost zero (0.5%) in 1998 and -7.9% in the first quarter of 1999 (SSB, 1999).

economic activities like traditional row crops to labor intensive activities in agriculture, manufacturing and other industrial activities (Anderson 1990).

Agricultural Production Growth

Agricultural production growth is one of the main accomplishments of China's development and national food security policies. Production growth rates have outpaced population growth since the early 1950s, with the exception of the famine years of the late 1950s and early 1960s. Even between 1970 and 1978, when much of the economy was reeling from the effects of the Cultural Revolution, grain production grew at 2.8 percent annually (Table 3). Oil crop production grew 2.1 percent annually and fruit and meat output increased by 6.6 and 4.4 percent.

Decollectivization, price increases, and relaxation of marketing restrictions on most agricultural products fueled China's food economy take off (1978 to 1984). Grain production increased 4.7 percent annually, and fruit output rose 7.2 percent (Table 3). Oil crop, livestock, and aquatic production all grew spectacularly, expanding annually in real value terms by 14.9 percent, 9.0 percent, and 7.9 percent respectively.

After the efficiency gains of the shift to the household responsibility system were exhausted by the mid-1980s, however, agricultural production decelerated (Table 3). The decline was most pronounced for grains and oil crops, sectors in which prices and markets were still highly regulated. Growth rates of other crops, livestock, poultry, and fishery products have remained steady or increased during the reform period in response to rising demand and market and price liberalization.

Past studies demonstrate that a number of factors contributed simultaneously to agricultural growth during the reform period, both the early and late parts of the period. The earliest empirical efforts focused on the contributions of reform policies (McMillan et. al. 1989; Fan, 1991; Lin, 1992). These studies conclude that increased productivity was primarily a result of institutional innovations, particularly the rural household responsibility system that restored the primacy of the individual household in place of the collective production team system as the basic unit of production and management in rural China.

Recent studies show that technological change has become the primary engine of agricultural growth since the completion of the household responsibility system reform in 1984 (Huang and Rozelle, 1996; and Huang, Rozelle, and Rosegrant, 1999; Fan and Pardey, 1997). The results also indicate that reforms beyond decollectivization have high potential to affect agricultural growth. Price policy has had a sharp influence on the growth of both grain and cash crops during the post- reform period. Favorable output to input price ratios contributed to rapid growth in the early 1980s. However, the new market force is a two-edged sword. The deterioration of China's price ratio, caused by gradually falling output prices and rapidly rising input prices, was one cause of the agricultural production slowdown of the late 1980s and 1990s. Rising off-farm labor opportunities and land use opportunity costs constrained the growth of grain output throughout that period and the growth of cash crops since 1985.

Growing environmental degradation, including erosion, salinization, and the loss of cultivated land also may be affecting China's agricultural supply. Both erosion and salinization have increased since the 1970s, to the detriment of grain, rice, and other agricultural production output (Huang and Rozelle, 1995).

III. Agricultural Development Strategy and Policies

Food self-sufficiency has been and will continue to be the central goal of China's agricultural policy. The Ninth Five-year Plan for 1996-2000 and the National Long Term Economic Plan both call for continued agricultural production growth, annual farmer income growth of four percent, maintenance of "near" food self-sufficiency, and elimination of absolute poverty. However, a review of current development policies raises many questions on the credibility of achieving the above development goals simultaneously. China's policies can play a substantial role in improving its agricultural productivity if the policies are formulated appropriately.

Fiscal and Financial Policies

While government expenditure in agriculture has shown a general increasing trend in the reform period, its share of total investment and the ratio of agricultural investment's share to agricultural GDP's share have shown a declining trend since 1980s (Huang, 1999a). Recently, officials have stated their intentions to raise the priority of public investment in agriculture. However, due to the weaknesses of the nation's fiscal system, the new policy to increase public investment in agriculture has only just begun to be implemented (Nyberg and Rozelle, 1999). There are many policies and regulations that have been promulgated regarding the provision of a minimum level of agricultural and public goods, but there is no budget to back them up. Without sufficient budgets, policies almost invariably cannot be effectively carried out.

To have a better understanding of government policy bias among sectors, we look at both fiscal and financial policies as well as the state agricultural procurement policy (a policy that we interpret as being an implicit tax on farmers). Table 4 shows that government fiscal expenditure on agriculture has been consistently higher than the fiscal revenue that they have generated from the agricultural tax and other official fees collected from agriculture. However, this fiscal revenue from explicit tax on agriculture and fees is only small portion of the total agricultural capital contribution to industry and to the urban sector.

A significant capital outflow from agriculture to industry occurred in the last two decades through the financial system, particularly through Rural Credit Cooperatives. A much higher value of capital has flowed from rural to urban (as well as the volume that flows from agriculture to industry) clearly showing that capital accumulated from agriculture not only supports industrialization in the urban sector but also provides notable financial resources for the development of rural industry.

After accounting for the implicit tax through the government procurement system, China extracted an accumulated total of 313 billion yuan (in 1985 prices) from the agricultural sector for the nation's industrialization effort in 1978-96, and about 563 billion yuan from the rural sector for the urban economy during the same period. Moreover, the shifting of capital from agriculture to industry, and from the rural sector to the urban, has shown an increasing trend since the reforms were initiated in the late 1970s. While much more research is needed to analyze the determinants of these trends and inefficiencies (if any) that distortions in the economy are causing, with the projected investment needs of the agricultural economy, it is unclear how officials will be able to mobilize capital to meet the nation's goal of raising investment in agriculture in order to raise agricultural productivity.

Food Price and Marketing Policies

Price and market reforms are key components of China's development policy shift from a socialist to a market-oriented economy. The price and market reforms initiated in the late 1970's were aimed at raising farm level prices and gradually liberalizing the market. These reforms included increases in government procurement quota prices, reduction in the quota levels, introduction of above quota bonuses, negotiated procurement of surplus production of grains, oils, and most other commodities, and flexibility in marketing of surplus production of all categories of agricultural products privately. Nonetheless, the limited and differential rate of liberalization of the agricultural markets have had substantial impact on productivity and commodity composition at the household and national levels (Lin, 1992; Huang, Rosegrant and Rozelle, 1995). The shift from the collective to household responsibility system also raised the price responsiveness of farm-households (Lin, 1991a). As the right to private trading was extended to include surplus output of all categories of agricultural products after contractual obligations to the state were fulfilled, the foundations of the state marketing system began to be undermined (Rozelle, et al., 1997).

After a record growth in agricultural production in 1984 and 1985, a second stage of price and market reforms was announced in 1985 aimed at radically limiting the scope of government price and market interventions and further enlarging the role of market allocation. Farmers and state commercial departments were to "negotiate" purchase contracts before the planting season at the weighted average quota and above quota prices. Other than for grains and cotton, the intention was to gradually eliminate planned procurement of agricultural products; government commercial departments may only continue to buy and sell in the market. The contract system, however, also resulted in a negative impact on agricultural production as the marginal price to the producer declined (Sicular, 1991; 1995).

Because of the sharp drop in the growth of agricultural production and food price inflation in the late 1980s, implementation of the new policy was stalled. Mandatory procurement of grains, oil crops, and cotton was continued. To provide more incentive for farmers to raise productivity and sell to the government, contract prices were raised over time. Despite this, the increase in the nominal agricultural procurement price was lower than the inflation rate, which led to a decline in real farm gate prices.

As agricultural production and prices stabilized in 1990 to 1992, another attempt was made in early 1993 to abolish the compulsory quota system and the sale at ration prices to consumers. While both the state distribution and procurement systems was substantially liberalized, the policy was reversed when food price inflation reappeared in 1994. Since then, several new policies have been implemented. Government grain procurement once again became compulsory. The provincial governor's "Rice Bag" responsibility system was introduced in 1994 to 1995.

With three record levels of grain production in China in 1995, 1996, and 1997, almost zero or negative inflation since 1997, rising grain stocks, declining prices in food markets, and rising financial burden in state grain marketing, China was in a position to take further steps to liberalize its domestic grain market. Indeed, the "free market" had continued to flourish notwithstanding the strong control maintained over the grain market before the mid-1990s. However, the central government initiated a controversial policy change in the grain marketing system in 1998.[2] Under the 1998 policy, individuals and private companies are prohibited to procure grain from farmers, but are allowed to operate in wholesale and retail markets.[3] Commercial arms of grain bureaus and the grain reserve system are the only ones who will procure grain from farmers. The ban on private grain procurement was considered by the government as a pre-condition to eliminate government's financial burden. Grain quota procurement prices were set at 20 to 30 percent higher than market prices. Prices of grain sold by grain bureaus directly to markets or to private traders should be set at a level higher than procurement prices to fully cover marketing operation cost and therefore avoiding losses in marketing by grain bureaus. However, few economists considered the policy achieved any of its goals.

Because of the high costs of monitoring and inspecting grain market, private traders have been continuing purchasing grain from farmers since the policy was implemented. Because the marketing operation costs of private traders are much lower than that of the grain bureaus, although the government grain procurement prices were set at the levels much higher than the market equilibrium prices in 1998, private traders could offer farmers even higher grain prices than the government procurement prices and sold grain in the market at the prices lower than those by grain bureaus. The results of this policy are: rising transaction costs of private traders, increasing grain stocks held by grain bureau, adverse effects on resource allocation, and diversification of agricultural production.

Table 5 shows the estimates of nominal and real protection rates based on various producers' prices from 1985 to 1998 for selected agricultural commodities namely, rice, wheat, maize, and soybean. The nation's policy to make farmers submit a mandatory delivery quota at below market prices has consistently represented a tax on (or disprotection to) farmers. The introduction of negotiated procurement reduced the tax from government procurement operations. Not surprisingly, the most heavily taxed commodities are the exportable ones, especially rice. Wheat, China's main imported commodity, has received more favorable treatment. Aside from the lower quota price NPR (Nominal Protection Rate) for rice, the higher proportion of grain procurement at the lower quota price is typically higher for rice, when compared to maize and soybeans. The NPRs for wheat and maize at free market prices have ranged from 20 to 25 percent since the mid-1990s.

In sum, despite substantial efforts to liberalize the price and market structure of the agricultural sector, most major agricultural commodities continue to be heavily penalized by commodity specific policies through procurement (except for 1998). When the impact of the

[2] The goals of the grain market reform in 1998 are: to improve the efficiency of the grain marketing system and to reduce central government's fiscal burden in financing grain circulation and the reserve system.

[3] By the policy, grain marketed by the private sector in wholesale and retail markets should come from the state grain bureau.

overvaluation of the domestic currency due to the trade protection system is considered, the agricultural incentives would get even worse. These distortions in price incentives depress agricultural production and redistribute income from farmers to urban consumers and the agro-processing sector. Improving farmer's incentives in agricultural production, raising agricultural productivity and farmers' income requires further liberalization of China’s agricultural markets, particularly the grain market.

Foreign Exchange and Trade Policies

China has become a much more open economy with foreign trade growing faster than GDP. The trade dependence ratio, the share of exports and imports in GDP, rose from 12 percent in 1980 to 23 percent in 1985, and to 36 percent by 1997 (SSB State Statistical Bureau?). Total value of agricultural trade of China increased from US$ 11.6 billion in 1980 to US$ 31.2 billions in 1997. However, the share of agricultural trade in the total trade value fell from 30.4 percent in 1980 to 10 percent in 1997 due to the even faster growth of trade in manufactured goods.

China’s Open Door policy contributed to this rapid growth of the external economy and to greater reliance on both domestic and international trade to meet consumer demand. Historically, the overvaluation of domestic currency for trade protection purposes had reduced agricultural incentives. Real exchange rates remained constant and even appreciated during the 30 years prior to the reforms. After the reform, however, the exchange rate depreciated rapidly, with the exception of several years of domestic price inflation during the mid-1980s. From 1978 to 1992, the real exchange rate depreciated more than 400 percent. Falling exchange rates increased export competitiveness and have contributed to China’s phenomenal export growth record (i.e. non-grain food products) and the spectacular national economic performance of the 1980s.

In recent years, however, the situation has changed. From 1992 to 1997, the real exchange rate has appreciated by about 30 percent. Although the NPRs of agricultural products at free market prices have been positive since 1990s, most agricultural product price protection rates are negative if the real over-valuation of the domestic currency is considered (real effective protection rates, Table 5). In fact, when viewed from this point, China has provided its agricultural sector little protection in recent years.

Land Use Policy

Nearly every farm household in China is endowed with land. Land ownership rests with the village (or collective) and is contracted or otherwise allocated to households. Legal tenure security on contracted land was recently extended from 15 to 30 years, but village leaders frequently do not follow these policy directives. The dynamics of household and village demographics and other policy pressures often induce local authorities to reallocate land prior to contract expiration. Although there are most likely significant long-term gains to productivity that would be associated with better tenure, several analyses have demonstrated that China’s land tenure system has impacted only marginally on agricultural production (Brandt et al., 2000). However, the absence of secure tenure rights does prevent farmers from using land as collateral and limits their access to formal credit markets.

Formal land rental markets are infrequently observed in China. Informal arrangements allow households to transfer short-term use rights to others for a fee—including tax and quota liabilities—although the proportion of land rented is very small. As increasing numbers of rural residents migrate or otherwise obtain non-agricultural employment, inefficiencies in land utilization arise when farmers cannot rent out their land. One of the challenges facing the government today is the search for a mechanism that permits the remaining full-time farmers to access additional farm land and improves incomes by raising the land/labor ratio.

Despite the benefits that farmers would receive if land were privatized or if land rights were more secure, a number of household surveys have determined that most farmers prefer collective ownership and periodic land adjustments based on demographic dynamics (Kung and Liu, 1997). Therefore, an abrupt change in land property rights, such as privatization, might have significant costs. The pressures to privatize agricultural land in China are actually quite low.

The effects of equitable distribution of land to farmers on food security and poverty are obvious. But land fragmentation and small size of farms constrain the growth of labor productivity and farmer's income. Probably more than any single feature, the size of farms in China defines its agriculture. More than 70 percent of the population, nearly 900 million people, lives in rural areas. Since only 10 percent of China's land is arable, the enormous number of farm households means that China has nearly the smallest farms in the world, and farm size is falling (Table 6). In 1980, the average size was only 0.56 hectares per farm (around 0.15 hectares per capita). By 1997, farm size had fallen to 0.40 hectares. Despite their minute size, China's farms still produce more than half of the income for rural households. The rise in nonagricultural income, however, accounts for most of the gains in per capita rural incomes in the reform era and work off the farm is the most likely way that rural residents will escape poverty.

The small scale of farming and increasing importance of the non-agricultural sector have important implications for officials who need farmers to adopt new technology to increase production and raise productivity. In most cases, farmers must incur a fixed cost before they can adopt or efficiently use most new technologies. The cost may be denominated in terms of the time it takes to search for the new technology or in effort and expenditures it takes to learn how to use it effectively. Since the outcome of adopting a new method of farming is uncertain, part of the cost may be the effort a farmer exerts to protect the household from the risks of the new technology (e.g., partial adoption; etc.). If the costs are fixed, the size of the operation on which the new breakthrough will be used is a factor in whether or not a farmer will decide to adopt or not. If the farm size is large, a farmer will be willing to exert a lot of effort and money experimenting with new technologies, since on a per unit of land basis, the cost will be small. In contrast, when the farm is small, unless the prospects of increased profits are large, farmers will be relatively less enthusiastic to look for new technologies. It is not that farmers resist new technology, it is just that the marginal benefit of the extra investment that is required to discover the appropriate new breakthrough or method of cultivating is less than the cost. Rising wages off the farm also may slow down adoption, since the cost of adoption will be higher.

In a growing economy characterized by a large number of small farmers, the government that is interested in increasing the growth rate of agriculture may find that it can play an important role in the creation and delivery of new technology. The idea is that the government must reduce the cost of discovery and/or learning. For example, providing extension services to farmers can reduce the cost to the farmer as the information is brought to them. Making technologies available through government-sponsored seed companies that will guarantee the reliability of the product and provide advice through the local seed station or network of township and village leaders can also reduce search and adoption costs and reduce the risk of adoption.

Rural Development and Labor Market Development Policies

China's experience in development of the rural enterprises shows the importance of expanding non-agricultural sectors in the rural areas to generate employment for rural labor and raising agricultural labor productivity (Table 7). Rural industrialization plays a vital role in reducing the agricultural labor surplus. Agricultural labor productivity grew at about 10 percent annually in the entire reform period and the growth has been on a rising trend since the late 1970s. It is regarded as one of the major successes of the country's reforming economy.

Rural enterprise's (or RE) share in GDP rose significantly from 2 to 4 percent in 1970s to 28 percent by 1997 and dominated the export sector by the mid-1990s (Table 6). Now REs employ nearly 30 percent of rural labor and is the major source of rural employment creation. With the rapid growth of REs in China, the diversification of farmer income has been remarkable. The contribution of non-farm income share in farmer's income rose sharply from 17 percent in 1980 to 39 percent in 1997 (Table 6).

Prior to the rural reforms, underemployment had been a persistent problem in rural China. This became more apparent as efficiency gains in agriculture during the reforms reduced the labor input needed for crop production. During the same period, the rural labor force grew 2 to 2.5 percent annually with more than 10 million new entrants each year during the 1980s. The increase in rural labor resources combined with land scarcity limited the absorptive capacity of agricultural employment and could have caused an enormous labor surplus, slowed down farmer's income growth, and limited the extent of poverty reduction if the non-agricultural sector had not developed appropriately.

Many countries commonly promoted rural to urban migration to cope with such an abundance of labor in the early part of the century. However, massive, un-managed migration has often resulted in a number of problems for urban society, such as rising levels of pollution, increased congestion, housing shortages, inadequate social services, and a rising proportion of the population in urban poverty. China's experience in developing rural enterprise shows how the expansion of non-agricultural activities in the rural areas can generate employment to provide jobs for a growing rural labor force. Indeed, rural enterprises now dominate many industrial sectors in China, including textiles, clothing, farm machinery and equipment, other simple machinery, construction materials, food processing, and a variety of consumer goods.

At the same time, there are still a number of factors hindering the adjustment process of labor. There are natural barriers, such as moving costs, which exist within all economies, regardless of the nature of its structure. China's factor markets still contain a number of structural imperfections, such as employment priority for local workers, housing shortages, and the urban household registration system (Lin, 1991b; Lyons, 1992; Rozelle, 1994; Lohmar, 1999). One of the costs of these kinds of barriers is that they may slow down the mobility of factors among alternative economic activities, reducing the efficiency of the sector's producers.

Anti-Poverty Policy

Both central and local governments are committed to poverty alleviation. In the early 1980s, tremendous progress was made in addressing China's poverty problem (Nyberg and Rozelle, 1999). According to government poverty statistics, the number of people under the poverty line in the rural area declined from 260 million in 1978 to 89 million in 1984. The incidence of poverty (the share of the poor in the total population) declined from 32.9 percent to 11.0 percent during the period. Much of the credit for the early reduction in poverty is attributed to the rapid rural economic growth that resulted from better incentives and the government's rural reform program (Lardy, 1983). However, the adequacy of financial resources for the poverty area's development is a challenge for officials charged with running China's poor area development. While total funds for poor areas increased in nominal terms over time, real investment in the poor areas declined in the late 1980s and early 1990s.

With the poor increasingly located in the more remote areas, the change in lending strategy from the household to economic entities, the inadequacy of financial resources, and slower growth of the rural economy, the progress achieved since the early 1980s has slowed. There were about 42 million people still living below the official poverty line in 1998, or approximately 5 percent of the rural population.

The government originally set a goal of eliminating absolute poverty for the remaining 42 million people by the end of this century. To achieve the above, the program called for increased funding for the poor areas, particularly for the 592 poor counties that are designated by the central government. However, the increase of funds for the poor areas has not been realized since 1994. Indeed, the real investment in the poor area declined by 33 percent between 1993 and 1996. Although the investment in poor areas rose in 1997, it was still lower than the level of funding allocated in the first year (1994) of the 8-7 program's push to eliminate poverty. For a more comprehensive review of poverty policy, see the chapter by Rozelle, Zhang , and Huang in this volume.

Technology Development Policies

After the 1960s, China's research institutions grew rapidly, from almost none in the 1950s, producing a steady flow of new varieties and other technologies. China's farmers used semi-dwarf seed varieties several years before the release of Green Revolution technology elsewhere in the world. China was the first country to develop and extend the use of hybrid rice. Chinese-bred corn, wheat, and sweet potatoes were comparable to the best in the world in the pre-reform era (Stone, 1988).

A nationwide reform in research was launched in the mid-1980s. The reforms attempted to increase research productivity by shifting funding from institutional support to competitive grants, supporting research useful for economic development, and encouraging applied research institutes to support themselves by selling the technology they produce. Although competitive grant programs may have increased the efficacy of China's agricultural research system, reliance on commercial revenue to subsidize research and compensate for public funding shortfalls has weakened it. Empirical evidence demonstrates the declining efficacy of

China's agricultural research capabilities in the early 1990s (Jin et, al., 1998).

Taking into account the role that science and technology played in raising agricultural productivity and the recent deterioration of the research system, the Chinese government concludes in the Long Term Plan for 2010 that China will rely on new technology, particularly new crop and livestock varieties, to raise future agricultural production. Technology is at the center of the "advancement of agriculture" (kejiao xingnong). The exhortation of Jiang Zemin, President of China, is widely quoted, "We are counting on breakthroughs of our agricultural research system. We need to begin re-inventing China's agricultural sciences and technology revolution". The government has begun an ambitious program promoting biotechnology and has pushed a number of high profile technology projects, such as hybrid rice. It has set ambitious funding growth targets.

At the same time, however, budgetary cutbacks, administrative decentralization, perceptions of inefficiencies, and inter-ministerial infighting has led to falling support for agricultural research, severe reductions in extension staff, and half-hearted attempts to reform the seed industry. Fiscal constraints have limited China's ability to invest more on agricultural research and extension since the mid-1980s (Table 8). Agricultural research investment intensity has been declining over time. By the mid-1990s, the intensity of both agricultural research and extension expenditure was among the lowest in the world (Huang, Hu, and Fan, 1998b).

Today, the record on the reform of the agricultural technology system is mixed and its impact on new technological developments and crop productivity is unclear. Leaders have launched wide ranging, deeply penetrating reforms in research institutes, commercialized a wide number of extension activities, and begun to liberalize seed markets. Progress in reorganization of the management and financing of research reform varies greatly over time, across space, and among the components of the system. Different indicators of research output and agricultural productivity paint different pictures on the success or failure of the changes (Jin et al., 1998).

IV. Technology Changes and Growth of Agricultural Productivity

The objective of this section is to report the results of our recent study on the impact of national investment into research and extension in China. Due to the enormous data requirements, we had to limit our attention to major crops (rice, wheat, soybean, and maize) in major growing provinces.[4]

Crop Productivity in China During the Reform

Historically estimates of China's cropping total factor productivity (TFP) have been controversial. Differences in the estimates between Tang and Stone (1980) and Wiens (1982) created a debate on the success of pre-reform agriculture. The major work documenting TFP growth in the reform era, Wen (1993), showed progress and stagnation, depending on the time

[4] For detail, see Huang et al., 1999.

period of analysis. On the one hand, Wen's work confirms the efficiency analyses of McMillan, et al. (1989) and Lin (1992), showing that rapid TFP growth was at least in part behind the rural economy's miracle growth in the early 1980s. However, Wen's work , which only went through 1990, created the impression that the agricultural sector was in trouble, since aggregate TFP growth stagnated after 1985.

Table 9 shows a general upward, though variable trend of TFP in rice, wheat, maize, and soybean productivity. Although the rate of increase varies by time period, in general, the TFP of all crops rose rapidly in the early 1980s, the earliest period of China's reforms: wheat increased by more than 90 percent between 1979 and 1985; rice by 54 percent; soybeans by more than 43 percent. Maize rose by 56 percent.

Such an unparalleled rise in TFPs, however, could not be sustained. Average TFP was at about the same level in 1990 as in 1985. The stagnant TFP trends, the same discussed by Wen (1993) who looks at the entire agricultural sector, are also evident in the grain sector. These trends have generated great discussion in China over what has caused yield slowdowns during this period. The debate usually focuses on land rights, commodity pricing policy, the availability and price of inputs, and the structural transformation of the rural economy (i.e., the expansion of rural industries and rural income diversification).

The rise in TFP, however, restarts in the 1990s. Productivity of wheat, the most successful crop, rises by more than 24 percentage points between 1990 and 1995. That of soybeans, a close second, increases by about 20 percentage points, albeit from a lower base. If one discounts 1994 and 1995, the TFP growth rates of rice and maize nearly match those of wheat and soybeans. The productivity of rice, however, moves down sharply in the mid-1990s, and ends up below that of soybeans. Maize rises as much as wheat in the early 1990s, but like rice, it falls back in 1994 and 1995.

Although TFP growth patterns for all of the crops aggregated at the national level are similar, trends of the various sample provinces—even within a crop—vary sharply (Huang et al. 1999). For example, in the case of wheat, TFP rises as much as 3 to 4 percent annually in Hebei and Shandong. Productivity gains in Shanxi and Sichuan are less than 1.5 percent annually. The overall gains in rice TFP varies even more, ranging from only 21 percent in Hebei to more than 140 percent in Jilin.

Agricultural Technology in China

China has traditionally had one of the strongest research systems in the world. China's agricultural scientists and the government support system developed and disseminated technology throughout the People's Republic period. By the early 1980s, China's research and development system for agriculture was at its peak. It had just made several major breakthroughs. Its level of national funding had been increasing. In part as a consequence of past investments, throughout the reform era, breeders have turned out a constant stream of varieties. Since 1982, rice farmers in China have used about 400 "major" varieties each year. Rice farmers in each province use around 25 major varieties per year. In the case of wheat, because there is no single dominant variety like hybrid rice (for which several varieties make up a large proportion of the nation's sown area), the total number of varieties per year nationally and the number per province are expected to be larger. In fact, wheat and maize breeders enjoyed less success. Wheat farmers in each province use around 23 varieties each year; maize farmers, on average, use 13 varieties. There are even fewer major soybean varieties in China both in total and on a per province basis. One reason may be that the research system has not traditionally centered its attention on the crop. Additionally, China is the center of origin for soybeans and there are many more small, traditional varieties that are still being grown.

Chinese farmers adopt new varieties with great regularity. The rate of turnover of varieties of major rice, wheat, maize, and soybeans in China is very impressive.[5] Between the early 1980s and 1995, China's farmers turn their varieties over at a rate that ranges from about 13 to 45 percent. Maize farmers turn their varieties over the fastest, averaging more than 33 percent per year. This means that every three years farmers *on average* replace all of the varieties in their fields. Rice and wheat farmers adopt varieties at a somewhat slower rate, changing their varieties every 4 to 5 years. Soybean farmers adopt varieties at the slowest rate, changing their varieties every 6 years. Again, this might be consistent with the fact that the research system has not traditionally centered its attention on soybean. From conversations with those familiar with grain cultivation in the US, Mexico, and India, as national averages, the turnover rates rival those found in the rice bowls and wheat baskets of the developing and developed world.

To examine the nature of technology more closely, we create two measures that can demonstrate the quality of technology being created by the research system, and the technological choices being made by farmers. Using the experiment station yield of each major variety during the year that the variety was certified, two measures are developed: a "yield envelope" variable; and a "adopted yield potential" variable. The yield envelope, which is created by using the *highest* yield of any *one* major variety in the field in each province during a given year, is a measure of the ultimate yield potential of the current technology of each province's research system. The other variable, adopted yield potential, is the unweighted *average* of the experiment station yields of *all* major varieties that have been adopted by farmers. In our analysis, since farmers are the ones who adopt these varieties, we consider this as a measure of technology adoption. In addition to the rapid adoption of new technology, China's research system also has created a steady stream of yield-increasing technology (Table 10). The yield envelopes for rice and maize, especially, have moved out at nearly 2.5 percent per year largely because of the development of hybrid rice and maize varieties. Albeit more modest, the yield envelopes of wheat (1.3 percent) and soybeans (1.3 percent) also have risen significantly during the reforms.

Farmers, however, have not always chosen (or been able to choose) the highest yielding varieties. The average yield potential (as measured by the yield at the experiment station of each variety during the year it was certified) of major varieties in the sample area has risen between 0.6 (soybeans) and 1.8 (maize) percent per year during the reforms (Table 10). When compared to the farmers' actual yields, in 1980 (1982 for wheat) the difference ranged from 31

---

[5] Variety turnover is a measure of how fast major varieties that first appear in China's field are able to replace the older varieties (See Huang et al., 1999 for details).

to 59 percent, gaps that are not high by the standard of developing countries (Pingali, Hossein, and Gerpacio, 1997; Pingali and Rosegrant, 1995). In part reflecting the rapid rise in inputs, the gap fell for all crops.

There are two ways to interpret the yield gaps that currently exist in China. On the one hand, there appears to be a great deal of yield potential left in varieties in the field and even more when considering the differences between actual yields and the yield envelope. On the other hand, the relatively small and narrowing gap (between 14 to 43 percent) between actual yields and adopted yield potential means that China's yield potential is not that large, and the nation needs more breakthroughs if the pace of yield growth is to be maintained.

In contrast, the gap between the yield envelope and adopted yield frontier has grown bigger, a fact that also has a number of different implications for China's future yield growth. It may be that high yielding varieties are not moving out into the field because of some physical, policy, or infrastructure constraint. On the other hand, it could be that farmers are finding other varieties rather than the highest yielding ones are the most effective at increasing efficient production. Farmers may choose to use varieties that have less than the highest yield because they demand some production or marketing trait (e.g., it requires lower input or is higher priced).

In addition to producing genetic material itself, China also has drawn heavily on the international research system for genetic material, especially for rice.[6] The International Rice Research Institute's (IRRI) material comprises a large share of China's rice germplasm. Nationwide, we can trace around 20 percent of the germplasm to IRRI varieties. The proportion varies greatly over time (from 16 to 25 percent) and also varies by province, reaching more than 40 percent in Hunan Province, one of China's largest rice growing provinces, in the late 1980s. Although the national use of wheat and maize materials from the CG system (varietal contribution by Consultant Group for International Agricultural Research, CGIAR, centers), mostly from CIMMYT, is lower (4 percent on nation average), there does exist great variability among provinces, and in some provinces material from the CG system (i.e. especially those in CIMMYT's mandate area, for example, Yunnan province for wheat or Guangxi Province for maize) makes up around half of the germplasm.

In summary, China's research system has created a lot of new technology and it has succeeded in getting farmers to adopt it at a rapid pace. The technology embodies significant levels of yield-increasing material that may prove to be an important determinant of productivity. The national research effort also is aided by the international agricultural research system. The rate of adoption of the highest yielding material, however, is much slower. China's yields and output certainly have grown due to increased use of inputs.

Technology, Extension, and Productivity

An econometric analysis of the determinants of new technology demonstrates the effectiveness of investments in the research system. The higher level of national stocks both accelerate the pace of varietal turnover and raise the yield potential embodied in major varieties

[6] It should also be remembered that China also has contributed significantly to the world stock of genetic resources for rice and soybeans, in particular.

used by farmers. If technology is the engine that will drive China's food supply in the future (Huang, Rozelle, and Rosegrant, 1999), the results in the study emphasize the necessity of maintaining the level and growth of public investment in crop research and development. Regardless of what factors contribute to the creation of China's rice, wheat, maize and soybean material, technology has a large and positive influence on TFP. The role of extension is less simple. The impact of extension can occur through its effect on spreading new seed technologies and providing other services that enhance farmer productivity.

Examining elasticities of TFP with respect to technology, extension, and the factors that affect technology help our understanding about what factors are contributing importantly to productivity (Table 11). The elasticities on the technology variable (varietal turnover) and the research investment (measured in research stock) variable are large for all crops. Research investment leads to increases in TFP through its impact on varietal turnover, and certainly is one of the reasons recent estimates of the returns to research calculate the IRR to be between 50 percent (Huang and Hu, forthcoming) and 70 to 100 percent (Fan, 1997). The fact that research investment increases productivity so much is also good for farmers who are sometimes hurt by policies that lead to price declines if they are not accompanied by cost reductions.

Although the elasticity on the CG variable (varietal contribution by Consultant Group for International Agricultural Research, CGIAR, centers) is small in examining its affect on TFP through varietal turnover, a direct more intuitive interpretation can be seen from the marginal effect. A percentage point rise in CG material in the case of rice increases TFP by nearly one percentage point. However, when its impact through the increase in yield potential is considered (Huang, et al., 1999), the marginal impact of CIMMYT material is small.[7] However, it should be noted that this effect is above and beyond the contribution that the CG system's germplasm has had on the varieties in the field. Between 4 to 25 percent of China's rice, wheat, and maize germplasm is contributed by CG varieties (Huang et al., 1999), and as a result, at least that much credit should be attributed to the CG system for the rise in TFP due to varietal turnover.

V. Trade Liberalization, Agricultural Technology and China's Food Deficit

Issues and Debates

China's ability to feed itself in the 21st century has been widely discussed and is a subject of much concern among researchers of China's agricultural economy. The preponderance of serious evidence indicates that China will be able to feed itself, although grain imports will probably rise over the next several decades. Yang and Tyers (1989) forecast that China would import roughly 50 mmt (metric million tons) annually in the late 1990s. Rozelle, Huang, and Rosegrant (1996) and Huang, Rozelle, and Rosegrant (1999) predict that China will need to

---

[7] This may result from the fact that some provinces in south and west China where CIMMYT varieties are adopted, are excluded from the analysis due to lack of data. Currently, efforts are underway to collect data for these missing provinces.

import 30-40 mmt annually to meet domestic demand for the first two decades of the twenty first century. Most international food trade and production specialists believe that current suppliers can meet China's rising import demands without long-term price increases or threats to world food security.

The impact of trade liberalization and China's accession to WTO on domestic grain production and grain imports is of increasing concern to China's leaders. While most of the recent studies show that China will gain from joining WTO, its impacts on the economy varies substantially among sectors. Domestic agricultural production, particularly grain, cotton, oil crops and sugar crops, will decline with the trade liberalization (Huang and Chen, 1999).

Some researchers even predict that liberalization will lead to massive imports and a steep fall in China's rate of self-sufficiency. Garnaut and Ma (1992) forecast that China will face up to a 90 mmt grain shortage in 2000. Brown (1995) argues that China's grain production will fall between 216 and 378 mmt short of demand, forcing the nation to use foreign exchange earnings from the booming export sector to import enough grain to fill the gap. He predicts that China's imports will drain the world grain supplies, force prices up, and deny poorer nations the grain necessary to feed their populations.

Such a wide range of net import predictions is perplexing. China's emergence as either a major importer or a major exporter could have enormous consequences for world grain markets and prices. China is experiencing rapid development and transformation. Continual reforms and the dynamic nature of China's economy require that researchers update predictions frequently.

The purpose of this section is to report projection results that incorporate recent government policies and trade liberalization based on a projection model developed at the Center for Chinese Agricultural Policy (CCAP), CCAP's Agricultural Policy Simulation and Projection Model (CAPSiM).[8]

Given the high probability that China will soon enter WTO and that the process of trade liberalization will continue, we project China's food economy in the early 21st century under three alternative scenarios: a baseline run, a free trade regime only, and a free trade regime with the increase in public investment in agricultural research. While the baseline and complete free trade regime scenarios are extreme, they provide some bounds for our projections. The real situation, or the case for WTO, is likely to fall somewhere in between. The baseline scenario assumes that the current policies will be continued without change and that China will not participate in WTO in the future. The free trade regime assumes that China will be rapidly liberalizing its agricultural sector after 2000 and be completely unprotected by 2005. We also examine what would happen should China liberalize while increasing public investment. The annual growth rate of agricultural research expenditures in real terms is 4 percent under both the baseline and free trade scenarios; it is 6 percent under the free trade with increase in

---

[8] CAPSiM is a partial equilibrium model. Most of the elasticities are estimated econometrically with imposition of theoretically constraints. CAPSiM explicitly accounts for urbanization and market development (demand side), technology, agricultural investment, environmental trends and competition for labor and land use (supply side), as well as the price responses of both demand and supply (see Huang and Chen, 1999).

agricultural research expenditure scenario.

Agricultural Production, Demand and Trade

Baseline Scenario

Our baseline projections show that China's per capita food grain consumption has peaked in the late 1990s. The average rural resident will increase consumption until the year 2010 and then reduce demand thereafter. Urban food grain consumption declines over most of the projection period. Rural to urban migration leads to overall lower food demand.

Per capita demand for red meat is forecast to rise sharply throughout the projection period. China's consumers will increase 65 percent of their meat consumptions by 2020, from 17 to 28 kilograms per capita for pork, from 2 to 3 kilograms for beef, and 1 to 2 kilograms for mutton. Although rural demand growth lags behind the growth of urban demand, urbanization will shift people from rural into high-consumption urban areas. In 1996, an average urban resident consumed about 60 percent more red meat than his/her rural counterpart. Per capita demand for poultry and fish, although initially lower, will rise proportionally faster than red meat demand.

The projected red meat, poultry, and other animal product demand increase will spur aggregate feed grain demand. The baseline scenario predicts that demand for feed grain will increase to 175 mmt by 2010 and climb to 217 mmt by 2020 (Table 12).[9] Feed grain as a proportion of total grain utilization will grow from 27 percent in the mid-1990 to about 38 percent in 2020.

Aggregate grain demand, taking projected population growth into account, will reach 519 mmt by 2010, an increase of 23 percent over 1996 (422 mmt--Table 12). Although projected food demand levels off over the later projection period, grain demand will continue to increase in response to population growth and increased demand for animal products. Aggregate grain demand is expected to reach 578 mmt by the end of the forecast period.

Baseline projections predict that China's grain production will gradually fall behind increasing demand. Our projections forecast rising grain deficits as the annual growth rate of production falls behind demand. Imports will surge to 20 mmt in 2005 and stay at about 18 to 20 mmt in 2010-2020 (Table 12).

In the livestock and aquatic sector, the increases in the domestic production nearly match the increases in demand. The annual production growth rates of various animal products will range from 3 to 7 percent in the 2000 to 2020 period. The growth rates are equivalent to the growth rates of the demands for these products in the same period. The sector will continue to export, but the amounts of exported livestock products and fish will be small compared to the size of the total domestic production or consumption.

Impacts of Trade Liberalization

Under the free trade scenario, domestic grain prices (except those for rice) would fall. The fall in the domestic price of grain raises grain consumption and reduces growth in production.

---

[9] All figures measured in trade grain, rice in milled form, not unprocessed grain.

Compared to the baseline scenario, the gap between domestic supply and demand of grain would rise. China's net grain imports would increase to 60 mmt in 2005 (a level representing about 12 percent of the total grain consumption in China) and about 48-55 mmt in the 2010 to 2020 period (Table 12).

The most serious impacts of trade liberalization on grain are projected to be on maize, followed by wheat and soybeans. Under the free trade scenario, China's domestic maize production would fall far behind maize consumption. The production would grow annually by 0.7% only, while the consumption would grow by 5.9% as a result of the decline in maize price and surging feed demand for livestock production expansion after trade liberalization (2000 to 2005). Consequently, imports of maize would increase dramatically from less than 2 mmt in 2000 to 39 mmt (nearly one quarter of maize consumption in China) in 2005. China would likely be the world largest importer of maize in the coming years if the sector were completely liberalized.

Although wheat is a food grain, the consumption response of which to price change is weaker than that of feed grains, the impact of trade liberalization on wheat will be also substantial in the first few years as the wheat price declines. But projected wheat imports will fall after 2005 with decline in the population growth and the drop in demand due to migration (since urban residents consume less grain on a per capita basis than those in rural areas).

In contrast, rice producers are predicted to benefit from the trade liberalization. Under the free trade scenario, rice production will rise from 133 mmt in 2000 to 145 mmt in 2005 with an annual growth rate of 1.8 percent (compared to the baseline of 0.9 percent). The higher rate of production growth results from the rise in the rice price and the decline in the prices of inputs such as fertilizer and pesticide under free trade. In the meantime, the increase in the rice price reduces the annual rice consumption growth rate from 0.8 percent in the baseline to only 0.6 percent in the 2000 to 2005 period. The combined impacts of production and consumption imply that trade liberalization would result in substantial rice exports (7.12 mmt in 2005).

The impacts of trade liberalization on China's animal sector are also significant. But in contrast to the grain sector, the trade liberalization will raise domestic prices of pork and poultry substantially, and those of egg and fish moderately. The increase in the prices of these major animal products and a decrease in the feed price resulting from the trade liberalization would stimulate the domestic production of these products on the one hand, and dampen their consumption on the other hand. The exports of livestock and fish products would expand considerably, assuming China's exports did not run into other trade barriers (such as phyto-sanitary regulations). Trade liberalization is also expected to have significantly negative impacts on the productions of sugar crops, oil crops and cotton, and substantial positive impacts on horticulture and food processing industry (Huang, 2000).

Agricultural Technology and China's Grain Self-sufficiency

Food security has been and will continue to be one of the central goals of China's policy. While food security has many dimensions, one of the targets that was set by the Chinese government recently is to achieve a grain self-sufficiency level of above 95%. Although this level of grain self-sufficiency has been widely debated, any changes (including the trade liberalization) that might lower the grain self-sufficiency level below 95 percent in the long-term would get little support from the current leadership.

Table 13 presents China's grain self-sufficiency rates under the three scenarios for 1995-2020. The third scenario assumes that the growth rate of agricultural research expenditure in real terms rises from 4 percent (the assumption use in the other scenarios) to 6 percent during the entire projection period.

Under the baseline scenario, while China will be able to achieve one of the major components of its food security target (greater than 95 percent grain self-sufficiency) in the future, the costs associated with this scenario should not be ignored. All grain (except rice) prices in domestic markets will considerably exceed prices in the international markets. For example, maize, wheat and soybean domestic prices will exceed international prices by about 26, 20 and 21 percent, respectively, in 2005, and the gap between the domestic and international prices will widen thereafter, particularly for maize. The domestic price of maize will reach that of wheat by 2020. Whether the government budget and consumers can pay for the grain price protection policy and how livestock production and exports will be affected are issues that need to be considered.

Complete trade liberalization (the free trade scenario) will obviously challenge the current food security goal defined by the government. China's grain self-sufficiency rate will decline rapidly from 98% in the mid-1990s to 88.4% in 2005 (Table 13), a level unlikely to be accepted by the current government. Although the grain self-sufficiency rate will rise gradually after 2005, there will be still about 8% of domestic grain demand that needs to be met by imports in 2020.[10]

However, it is important to note that the most effective policy to improve China's food security and raise grain self-sufficiency level in the long term is to invest in agricultural productivity enhancement, such as agricultural R&D, rural infrastructure and water control (i.e., irrigation). Altering assumptions of investment in agricultural research has the greatest impact on production and trade balances in the long term. For example, Table 13 shows that China could essentially achieve its grain self-sufficiency target in the long term (after 2015) even under the free trade regime, if the annual growth rate in agricultural research investment rises from 4% to 6%. The result is hardly surprising given the large contributions that agricultural research, and the technology it has produced, have made to agricultural productivity in the past.

VI. Conclusions and Implications for Policy

China, the world's most populous country, is highly acclaimed for its ability to feed over one fifth of the world population with only seven percent of the world's arable land. Despite extremely limited natural resources and a population that has doubled over the last four

[10] However, it is worth to note that this is an extreme case (the free trade regime), representing a maximum impact of the trade liberalization on China's grain economy. The actual impacts of China's joining the WTO will be much lower than the results from this free trade scenario.

decades, per capita availability of food, household food security, and nutrition have all improved significantly. Increased domestic production is almost solely responsible for increased per capita food availability. However, China may face great challenges in reaching the goal of feeding its growing population and maintaining high food security in the coming decades if future policies do not further these goals.

Our projections show that, while China's importance as a world grain importer will increase over the coming decades, China will neither drain world grain markets nor become a major grain exporter if the future policies are formulated properly. Net grain imports over the next 3 decades are likely to be between 20 and 35 mmt annually. Accelerating demand for meat and feed grains are the major reasons for increased grain import predictions. China's grain economy will become increasingly feed grains oriented. However, under some situations, China could have to import up to 50 million tons or more (that is under complete trade liberalization without substantial increase in agricultural research investment).

Our estimates of China's net grain imports also could shift under various situations. We expect that relaxing any major policy assumptions or changing factors that we did not consider explicitly, such as competition for agricultural water use and declining returns to investment in agriculture and research, will have a significant impact on China's predicted food supply and demand.

Limited options in increasing food supplies intensify the challenge of meeting China's food security target. Although the policy and literature review in the previous sections illustrate that institutional reform, water control investments, price policies, and improvements to the environment contribute to higher food production, scare resources, current agricultural policies, and fiscal constraints may preclude leaders from implementing some of them. Decollectivization and fiscal reform have already been tapped for most of their gains. Likewise, five decades of development have exploited most of the easy gains from land and water investments (World Bank, 1997). Huang and Rozelle (1995) demonstrate the negative impact that increasing environmental stress has on output, but conclude that, in the current period, gains from launching a major effort to alleviate the problems will add little to supply at uncertain cost. The nation's budget crises, above all, bind the hands of officials even if investments in agricultural research promise high returns. Chronic budget shortfalls and looming trade agreements also effectively shut off the option of using East Asian style price policies to maintain production levels.

The constraints imposed on leaders by resource scarcity and political-economic realities increase the need to understand the scope for supply expansion from one of the most important sources of past supply growth, investments in the research system. The huge stock of research created by years of investment and the promising potential of technologies under development (from both domestic researchers and foreign sources) give leaders one solid policy handle.

China's research system has produced a steady flow of new crop varieties and other technologies since the 1950s. The robust growth of China's stock of research capital is in a large part responsible for dramatic agricultural growth rates. Improved technology has been the biggest factor, by far, behind grain production growth, and as such is a major source of increased food availability in China.

The analyses and results presented in this paper establish a basis for China's (and international) leaders and policy makers to confidently invest in the nation's agricultural research system. The basis for doing so primarily rests on the important of effects that technology, and the institutions that create, import, and spread it, have had on TFP in the past. The picture sketched by several our recent studies (Huang, Hu, and Fan, 1998; Huang and Hu, forthcoming; Huang, Rozelle, and Rosegrant, 1999) demonstrates that investment in new technology is many faceted. Public investments in breeding and the extension pay off in terms of higher TFP. The form of the technology matters, not only in how rich it is in terms of yield-enhancing material, but also in whether or not farmers will adopt it.

However, the recent decline in the government's budgetary commitment to research has weakened the system. The extension system is also extremely fragile and needs to be strengthened. Development of an efficient seed industry is not without roadblocks as appropriate supporting institutions (i.e. eliminating entry barriers, allowing the market to set prices, phasing out subsidies, and developing intellectual property rights) take time to mature.

After nearly two decades of reform, the grain bureau still requires farmers to deliver specified quantities of grain. While it is too early to evaluate the impacts of the new grain market reforms in the late 1990s on grain production, price and marketing, issues related to the ability and willingness of local governments to hold sufficient buffer stock for price stabilization need to be addressed. China should allow a greater role for the market to determine trade patterns in order to reap comparative advantage gains. This would probably mean increased overall agricultural trade domestically among provinces and internationally and a shift towards importing more land intensive agricultural products and exporting more labor intensive agricultural products. Policy steps to achieve comparative advantage gains might include removing implicit taxes on farmers and reforming domestic grain pricing and marketing system. In the past, China's agricultural policy on domestic agricultural product marketing has been biased against producers. Domestic price and marketing prices have consistently represented a tax on farmers in most of periods. Moreover, the most heavily taxed commodities are the exportable agricultural commodities.

In short, China's agriculture has achieved enormous gains in the past 20 years of reform. However, it also faces steep challenges in the future. Good development and transition policies are needed now more than ever.

References

Anderson, Kym. 1990. Comparative Advantages in China: Effects on Food, Feed, and Fiber Markets, Paris: Organization for Economic Cooperation and Development.

Brandt, Loren, Jikun Huang, Guo Li, and Scott Rozelle. 2000. Land Rights in China: Facts, Fictions, and Issues. Working Paper, Department of Agricultural and Resource Economics, University of California, Davis.

Brown, Lester. 1995. Who Will feed China? Wake-up Call for a Small Planet. The Worldwatch Environmental Alert Series, Worldwatch Institute.

Cheng, Guoqiang. 1998. "The Patterns of China's Agricultural Trade," *Intertrade,* No.11 (1998):4-6.

Fan, Shenggen. 1991. "Effects of Technological Change and Institutional Reform in Production Growth of Chinese Agriculture." *American Journal of Agricultural Economy*, May.

________. 1997. "Production and Productivity Growth in Chinese Agriculture: New Measurement and Evidence" *Food Policy* 22 (3 June): 213-228.

Fan, Shenggen and Phil Pardey. 1997. "Research Productivity and Output Growth in Chinese Agriculture," *Journal of Development Economics* Vol.53(June 1997):115-137.

Garnaut, Ross, and Guonan Ma. 1992. *Grain in China: A Report*. Canberra, Australia: East Asian Analytical Unit, Department of Foreign Affairs and Trade, 1992.

Huang, Jikun. 1999a. Performance, Prospects and Challenges for China's Agriculture in the 21st Century, A report submitted to RAP/FAO, Bangkok.

Huang, Jikun. 1999b. "Allocation Efficiency of Agricultural Resources in the 20-Year Reform", *China's Rural Survey*, No.1(1999):1-9, and No.2(1999):29-37.

Huang, Jikun and Chunlai Chen, 1999. Agricultural Trade Liberalization in China: Commodity and Local Agriculture Studies, A Project Report, ESCAP,UN.

Huang, Jikun, Hengyun Ma, and Scott Rozelle. 1998. "Rural Poverty and Investment Policy in the Poor Area in China," *Reform*, No.4(1998):72-83.

Huang, Jikun, Ruifa Hu and Xiandong Fan. 1998. "Agricultural Research Investment in China," *China Soft-Sciences,* 7(1998):95-101.

Huang, Jikun and Ruifa Hu. forthcoming. Agricultural R&D Investment and Policy in China. China's Agricultural S&T Press, Beijing [in press].

Huang, Jikun, Mark Rosegrant, and Scott Rozelle. 1995. "Public Investment, Technological Change and Agricultural Growth in China." Working Paper, Food Research Institute, Stanford University.

Huang, Jikun and Scott Rozelle. 1995. "Environmental Stress and Grain Yields in China."

American Journal of Agricultural Economics. 77(1995):853-864.

Huang, Jikun and Scott Rozelle. 1996. "Technological Change: Rediscovering the Engine of Productivity Growth in China's Agricultural Economy." *Journal of Development Economics* 49(1996):337-369.

Huang, Jikun, Scott Rozelle and Mark Rosegrant. 1999. "China's Food Economy to the 21th Century: Supply, Demand, and Trade", *Economic Development and Cultural Change,* 47(1999):737-766.

Huang, Jikun, Soctt Rozelle, Ruifa Hu, and Songqing Jin. 1999. "The Creation and Spread of Technology and Total Factor Productivity in China: An Analysis of the Contribution of China's Research System and CG-supplied Genetic Material," A Paper Presented on the Workshop on the Impact of National and International Research Programs on Total Factor Productivity in Developing Countries, 1999 AAEA's Annual Conference, Nashville.

Jin, Songqing, Carl Pray, Jikun Huang, and Scott Rozelle, 1998. "Commercializing Agricultural Research and Fungible Government Investment: Lessons from China," Working paper, UC Davis.

Kung, James and Shouying Liu. "Farmers Preferences Regarding Ownership and Land Tenure in Post Mao China," *The China Journal*, 38(July 1997):33-63.

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

Lin, Justin Yifu, 1991a. "The Household Responsibility System Reform and the Adoption of Hybrid Rice in China," *Journal of Development Economics,* 36(1991):353-72.

Lin, Justin Yifu. 1991b. "Prohibitions of Factor Market Exchanges and Technological Choice in Chinese Agriculture," *Journal of Development Studies* 27(4):1-15.

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

Lin, Justin Yifu. 1998. "How Did China Feed Itself in the Past? How Will China Feed Itself in the Future?" CIMMYT Economics Program, Second Distinguished Economist Lecture, 9 January 1998, Mexico.

Lin, Justin Yifu, Mingao Shen, and H. Zhao. 1996. Agricultural Research Priority in China: A Demand and Supply Analysis of Seed Improvement Research for Major Grain Crops in China. Beijing:China's Agriculture Press.

Lohmar, Bryan. 1999. "Rural Institutions and Labor Movement in China," Unpublished Ph.D. Dissertation, Department of Agricultural Economics, University of California, Davis.

Lyons, Thomas. 1992. "Market-Oriented Reform in China: Cautionary Tales," Working Papers on Transitions from State Socialism. Mario Einaudi Center for International Studies, Cornell University: Ithaca, NY, November.

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

MOA. 1997; 1998. China's Agricultural Development Report, 1997 and 1998, Beijing, Ministry of Agriculture.

MOA. 1980 to 1998. *Zhongguo Nongye Nianjian* [China Agricultural Yearbook], Beijing, China: China Agricultural Press.

Nyberg, Albert and Scott Rozelle. 1999. Accelerating China's Rural Transformation. Washington, D.C: The World Bank.

Pingali, P., M. Hossein, and R. Gerpacio. 1997. *Asian Rice Bowls*. CAB Press: London, UK.

Pingali, P. and Rosegrant. 1995. "Green Revolution Blues," Paper Presented at the Preconference on Development, American Agricultural Economics Association, Orlando, FL.

Rozelle, Scott. 1994. "Decision Making in China's Rural Economy: The Linkages Between Village Leaders and Farm Households." *China Quarterly* 137(March):99-124.

Rozelle, Scott and Jikun Huang. 1998. "Transition, Development and Wheat Supply in China," *Australian Journal of Agricultural Economics (forthcoming)*.

Rozelle, Scott, Jikun Huang and Mark Rosegrant. 1996. "Why China Will NOT Starve the World" *Choices* First Quarter, 1996:p18-24.

Rozelle, Scott, Albert Park, Jikun Huang and Hehui Jin. 1997. "Liberalization and Rural Market Integration in China," *American Journal of Agricultural Economics,* 79(May 1997):635-642.

State Science and Technology Commission. 1985 to 1997. "Statistical Compendium for Agricultural Research in China," SSTC, Beijing, China.

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*, Vol. 1:340-64.

Sicular, Terry.1995. "Redefining State, Plan and Market: China's Reforms in Agriculture Commerce," *China Quarterly* 143(December):1020-1046

SSB, ZGTJNJ. *Zhongguo Tongji Nianjian* [*China Statistical Yearbook]*. Beijing, China: China Statistical Press, 1980-99.

SSB, ZGRCTJNJ. *Zhongguo Nongcun Tongji Nianjian* [*China Rural Statistical Yearbook]*. Beijing, China: China Statistical Press, 1990-98.

Stone, Bruce. 1988. "Developments in Agricultural Technology," *China Quarterly* 16(December 1988).

Tang, A. M., and B. Stone. 1980. *Food Production in the People's Republic of China,* International Food Policy Research Institute (IFPRI) Report, May 1980.

Wang, Zhi. 1997.?

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

Wien, T.J. 1982. "Technological Change," in *The Chinese Agricultural Economy*, ed. R. Barker and R. Sinha (Boulder, Colo.: Westview, 1982).

World Bank. 1997. At China's Table: Food Security Options, Washington, DC: The World Bank.

Yang, Yongzheng and Rodney Tyers. 1989. "The Economic Costs of Food Self-Sufficiency in China." *World Development* 17(1989):237-253.

Table 1. Annual Growth Rates (%) of China's Economy, 1970-98

	Pre-reform	Reform period		
	1970-78	1979-84	1985-95	1996-98
Gross Domestic Product	4.9	8.5	9.7	8.7
Agriculture	2.7	7.1	4.0	4.0
Industry	6.8	8.2	12.8	10.7
Service	na	11.6	9.7	7.9
Foreign Trade	20.5	14.3	15.2	5.0
Import	21.7	12.7	13.4	10.8
Export	19.4	15.9	17.2	2.0
Population	1.8	1.4	1.4	1.0
GDP per capita	3.1	7.1	8.3	7.7

Note: Figure for GDP in 1970-78 is the growth rate of national income. Growth rates are computed using regression method. GDP growth rates refer to the value in real terms.

Source: State Statistical Bureau, China Statistical Yearbook, various issues.

Table 2. Changes in the Structure (%) of China's Economy, 1970-97.

	1970	1980	1985	1990	1995	1998
Share in GDP						
Agriculture	40	30	28	27	20	18
Industry	46	49	43	42	49	49
Services	13	21	29	31	31	33
Share in Agricultural output						
Farming (crop)	82	76	69	65	58	56
Forestry	2	4	5	4	4	3
Livestock	14	18	22	26	30	31
Fishery	2	2	4	5	8	10
Share in Employment						
Agriculture	81	69	62	60	52	50
Industry	10	18	21	21	23	23
Services	9	13	17	19	25	27
Share in Export						
Primary Products	na	50	51	26	14	11
Foods	na	17	14	11	7	6
Share in Import						
Primary Products	na	35	13	19	18	16
Foods	na	15	4	6	5	3
Share of Rural Population	83	81	76	72	71	70

Source: State Statistical Bureau, China Statistical Yearbook, various issues; and China Rural Statistical Yearbook, various issues.

Table 3. Annual Growth R~~r~~ate (%) of ~~a~~Agricultural ~~e~~Economy by ~~s~~Sector and ~~s~~Selected ~~a~~Agricultural ~~c~~Commodity, 1970-97.

	Pre-reform	Reform period		
	1970-78	1979-84	1985-95	1996-97
Agricultural output value	2.3	7.5	5.6	7.4
Crop	2.0	7.1	3.8	6.2
Forestry	6.2	8.8	3.9	4.5
Livestock	3.3	9.0	9.1	7.9
Fishery	5.0	7.9	13.7	12.7
Grain production	2.8	4.7	1.7	2.9
Rice	2.5	4.5	0.6	4.1
Wheat	7.0	7.9	1.9	9.8
Maize	7.0	3.7	4.7	-3.5
Soybean	-1.9	5.1	2.9	2.4
Cash crops				
Oil crops	2.1	14.9	4.4	-2.1
Cotton	-0.4	7.2	-0.3	-1.7
Fruits	6.6	7.2	12.7	9.9
Red meats	4.4	9.1	8.8	11.2
Pork	4.2	9.2	7.9	10.2

Note: Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms.

Source: State Statistical Bureau~~SB~~, Statistical Yearbook of China, various issues; MOA, Agricultural Yearbook of China, various issues.

Table 4. Capital Flow (billion yuan in 1985 price) from Agriculture/rural to Industry/urban through Fiscal, Financial (banking system) and Grain procurement Systems.

	Fiscal system		Financial system		Grain	Cash flow from	
	Agri to Industry	Rural to urban	Agri to Industry	Rural to Urban	Marketing (implicit tax)	Agri to Industry	Rural to Urban
1978	-15.2	-12.4			17.9	2.6	5.4
1980	-13.8	-10.8	5.0	1.6	16.6	7.7	7.3
1985	-6.6	4.2	8.3	2.5	5.6	7.3	12.4
1990	-11.2	5.8	19.5	11.9	15.5	23.8	33.2
1995	-7.4	44.4	18.3	10.0	18.1	29.0	72.4
1996	-6.5	42.2	15.7	9.8	11.8	21.0	63.8

Note: Capital net flow from agriculture to industry through Agricultural Bank of China, Agricultural Development Bank of China and Rural Credit Cooperative is based on the following formula:
[(agricultural enterprises' saving)$_t$ – (agricultural enterprises' saving)$_{t-1}$] + [(farmer's saving)$_t$ – (farmer's saving)$_{t-1}$] – [(loan to agriculture)$_t$ -(loan to agriculture)$_{t-1}$] ;

Capital net flow from rural to urban is based on the following formula:
[(TVE's saving)$_t$ – (TVE's saving)$_{t-1}$] + [(agricultural enterprises' saving)$_t$ – (agricultural enterprises' saving)$_{t-1}$] + [(farmer's saving)$_t$ – (farmer's saving)$_{t-1}$] – [(loan to agriculture)$_t$ -(loan to agriculture)$_{t-1}$].

Sources: Huang, Ma and Rozelle, 1998.

Table 5. Nominal and Effective ~~r~~Real ~~p~~Protection ~~r~~Rates of ~~g~~Grain, 1985-98

	Quota procurement price				Negotiated procurement price				Market price			
Year	Rice	Wheat	Maize	Soybean	Rice	Wheat	Maize	Soybean	Rice	Wheat	Maize	Soybean
					Nominal protection rate (%)							
1985-89	-30	4	-13	-13	-5	34	17	15	14	52	37	39
1990-94	-37	-14	-35	-32	-16	14	-7	7	-2	26	12	26
1995-98	-18	-9	-2	-26	-7	0	8	2	4	20	25	13
					Effective real protection rate (%)							
1985-89	-69	-54	-61	-61	-58	-42	-48	-49	-50	-34	-40	-38
1990-94	-70	-59	-69	-67	-60	-46	-55	-49	-53	-39	-46	-40
1995-98	-41	-35	-29	-48	-34	-29	-23	-28	-26	-14	-10	-20

Note: Imputed prices (value of imports or exports divided by quantity of imports or export) are used as the reference prices.

Source: Author's estimates.

Table 6. Rural Enterprise (RE) development in China, 1980-97.

	RE's share in rural labor (%)	RE's share in total GDP (%)	RE's share in total export (%)	Farm land size (ha/farm)	Non-farm income share (%)
1980	9	Na	na	0.56	17
1985	15	9	na	0.51	25
1990	22	14	15	0.43	26
1995	29	25	43	0.41	37
1996	30	26	48	0.41	38
1997	28	28	46	0.40	39

na: not available.

Table 7. Agricultural labor productivity in China, 1978-1997.

	Agriculture		Crop	
	Gross value	Value added	Gross value	Value added
Labor: yuan/year				
1978	491	358	557	368
1984	665	475	1358	915
1992	1314	831	1969	1205
1997	2990	1767	2721	1749
Annual growth rate (%)				
1979-84	6.3	4.9	19.8	20.5
1985-92	9.0	7.4	5.0	3.6
1993-97	18.7	16.9	7.1	8.3
78-97	10.4	8.8	10.2	10.2

Note: Values are measured in 1978 constant prices.
Source: Huang, 1999b.

Table 8. Agricultural research and extension expenditures in China, 1985-96

Year	Agricultural research expenditure			Share of	Agri.	Agri.	Publci agri
	Total (billion)	State finance (billion)	Development income (billion)	State finance (%)	research intensity (%)	extension expenditure (billion)	research intensity (%)
1985	2.20	1.65	0.55	75	0.52	na	na
1986	2.06	1.46	0.59	71	0.48	1.74	0.24
1987	2.00	1.35	0.65	68	0.44	1.81	0.32
1988	2.14	1.43	0.71	67	0.46	1.69	0.24
1989	2.14	1.45	0.71	67	0.47	1.55	0.23
1990	2.05	1.24	0.81	61	0.39	1.74	0.23
1991	2.31	1.25	1.07	54	0.43	1.99	0.25
1992	2.55	1.33	1.22	52	0.44	2.10	0.25
1993	2.67	1.27	1.40	48	0.46	2.08	0.23
1994	2.95	1.39	1.56	47	0.44	2.09	0.24
1995	2.83	1.42	1.41	50	0.39	2.17	0.23
1996	2.88	1.51	1.37	53	0.36	na	na

Note: values are in 1990 constant yuan. Agricultural research (extension) intensity is measured as the percentage of agricultural research (extension) expenditures to agricultural GDP. Agricultural research expenditure includes expenditures from government fiscal accounts (or public agricultural research investment) and commercial revenue generated by agricultural research institutes.
Source: The State Sciences and Technology Commission, Ministry of Finance.

Table 9. The trends of output, input and total productivity for rice, wheat, soybean and maize in China, 1979-95.

	TFP index (1979=100)				Output index (1979=100)				Input index (1979=100)			
Year	Rice	Wheat	Soybean	Maize	Rice	Wheat	Soybean	Maize	Rice	Wheat	Soybean	Maize
1979	100	100	100	100	100	100	100	100	100	100	100	100
1980	109	103	102	104	97	86	112	104	97	96	103	99
1981	120	123	111	107	100	97	127	101	93	89	115	93
1982	138	148	104	122	112	110	132	104	87	85	124	83
1983	146	178	133	147	118	137	134	118	87	87	100	80
1984	156	192	139	168	122	149	146	129	84	88	102	75
1985	154	191	143	156	115	150	167	111	80	88	118	69
1986	157	202	152	163	117	160	186	125	79	89	118	75
1987	158	206	158	172	117	157	202	141	78	86	126	79
1988	151	199	157	177	115	152	204	141	80	86	129	77
1989	158	200	131	163	123	164	158	138	82	92	125	83
1990	163	197	152	191	127	168	180	177	82	98	117	90
1991	165	195	153	200	123	166	182	181	78	94	117	86
1992	169	205	150	191	121	174	189	166	74	95	129	85
1993	179	223	159	210	117	187	272	179	70	94	177	84
1994	169	215	178	191	116	181	287	179	74	93	160	90
1995	154	221	171	185	121	186	243	195	77	91	147	101

Source: Huang et al., 1999.

Table 10. Experiment station yields, actual yields, and the yield gap in sample provinces in China, 1980 to 1995.

	1980 [c]	1995	Annual growth rate (%)
Rice			
Yield envelope [a] (tons/ha)	6.6	9.1	2.3
Adopted potential yield (*APY*) [b] (tons/ha)	6.1	7.2	1.4
Actual yield (tons/ha)	4.2	6.2	2.1
Percent gap between "Average experiment" and "Actual"	31%	14%	
Wheat [c]			
Yield envelope [a] (tons/ha)	6.3	7.5	1.3
Adopted potential yield (*APY*) [b] (tons/ha)	4.6	5.2	0.9
Actual yield (tons/ha)	1.9	3.6	3.2
Percent gap between "Average experiment" and "Actual"	58%	31%	
Maize			
Yield envelope [a] (tons/ha)	7.6	11.0	2.5
Adopted potential yield (*APY*) [b] (tons/ha)	6.1	7.9	1.8
Actual yield (tons/ha)	3.0	4.9	3.2
Percent gap between "Average experiment" and "Actual"	51%	38%	
Soybeans			
Yield envelope [a] (tons/ha)	2.9	3.5	1.3
Adopted potential yield (*APY*) [b] (tons/ha)	2.7	3.0	0.6
Actual yield (tons/ha)	1.1	1.7	3.1
Percent gap between "Average experiment" and "Actual"	59%	43%	

[a] Yield envelope is the *highest* experiment station yield of a variety that has been extended to the field. In this table, the figure is the average of sample provinces.
[b] Adopted yield potential is the *average* experiment station yields of *all* varieties being adopted by farmers. In this table, the figure is the average of sample provinces.
[c] Wheat data only extends to 1982, so figures for wheat are for that year, not 1980.

Source: Huang et al., 1999.

Table 11. Elasticities of TFP with respect to technology, extension, and other factors for rice, wheat, soybean and maize for China, 1982 to 1995.

Elasticity of TFP with respect to:	Rice	Wheat	Soybean	Maize
Direct				
Varietal turnover	0.31	0.28	0.27	0.32
Extension expenditure	-0.08	0 [a]	0.31	-0.32
Indirect				
Research stock	0.63	0.47	0.6	0.67
CG contribution	0[a]	0.01	0 [a]	0 [a]
Yield envelope	-0.12	0.14	-0.12	-0.11
Extension expenditure	0.05	0.10	0.08	0

[a] The 0 elasticity implies the that the coefficient was not significantly different than zero.

Source: Huang et al., 1999.

Table 12. Projections of grain production, demand, and net imports under various scenario, 2005-2020

	2005	2010	2020
Baseline:			
Production (mmt)	464	499	560
Net import (mmt)	20	20	18
Demand (mmt)	484	519	578
Food (mmt)	257	266	279
Feed (mmt)	151	175	217
Others (mmt)	76	78	83
Grain self-sufficiency (%)	96	96	97
Free trade regime			
Grain net import (mmt)	60	55	48
Maize (mmt)	39	47	64
Grain self-sufficiency (%)	88	89	92
Free trade regime + increase agri research expenditure (annual growth rate 4% → 6%)			
Grain net import (mmt)	60	52	17
Maize (mmt)	39	46	51
Grain self-sufficiency (%)	88	90	97

Source: Authors' projection.

Table 13. Grain self-sufficiency rates (%) under various scenarios, 1994-2020.

	1994-96	2005	2010	2020
Baseline:				
Total grain	98	96	96	97
Rice	100	99	100	101
Wheat	92	92	95	100
Maize	101	94	91	90
Soybean	100	101	102	102
Free trade				
Total grain	98	88	90	92
Rice	100	105	107	114
Wheat	92	83	88	97
Maize	101	76	74	72
Soybean	100	92	94	95
Free trade with raise in agri research expenditure*				
Total grain	98	88	90	97
Rice	100	105	108	119
Wheat	92	83	89	102
Maize	101	76	75	78
Soybean	100	92	95	101

*: The third scenario assumes that the growth rate of agricultural research expenditure in real terms rises from 4% (the assumption use in the other scenarios) to 6% during the entire period of the projection.