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Crop Farming in China

Technology, Markets, Institutions and the Use of Pesticides

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Outline

Abstract

During the past twenty years, China has experienced enormous economic growth, profound institutional reforms, and a fundamental transformation of society. As a result, farmers have become independent entrepreneurs and free markets for agricultural products and inputs have started to develop.

Changes in consumption patterns and the opening of markets has led to a shift in production mix towards products in which China has comparative advantages, i.e. away from grain production towards labor intensive cash crops such as fruits and vegetables. In line with the aim of the Chinese agricultural policy of keeping the country self sufficient in grain, the government is still involved in the marketing of grain, and it controls, too, the production and marketing of such respective inputs as seed and fertilizer.

Being a country of low arable land per capita, Chinese agriculture operates on a high yield level and there is a relative intensive use of labor, fertilizers and pesticides. In recent years, application of agricultural inputs has further expanded, and it is likely that this trend will continue as the economy grows further.

A cross-sectional analysis of Chinese agriculture shows that pesticides are applied most on those farms that cultivate crops with which the highest revenue per sown area can be achieved and that are most capital-intensive. From these results the following can be concluded: Continued economic growth and a further opening up of the agricultural commodities markets, together with the continuation of the Chinese government's policy of self-sufficiency, will accelerate farmers' propensity to use pesticides.

Kurzfassung

Während der vergangenen 20 Jahre erlebte China ein enormes Wirtschaftswachstum und fundamentale institutionelle Reformen verbunden mit einer tiefgreifenden Umwälzung der Gesellschaft. Dabei wurden die Bauern zu unabhängigen Unternehmern und freie Märkte begannen sich zu entwickeln.

Veränderte Konsumgewohnheiten und Marktöffnung führte zu einer Verschiebung in der landwirtschaftlichen Produktion in Richtung Produkte bei denen China komparative Vorteile hat, d.h. weg von Getreideproduktion in Richtung arbeitsintensive Cash Crops wie Früchte und Gemüse. Wegen dem Ziel der chinesischen Agrarpolitik, die Selbstversorgungen mit Getreide aufrechtzuerhalten, spielt die Regierung immer noch eine aktive Rolle bei der Getreidevermarktung und kontrolliert die Produktion und Vermarktung der entsprechenden Produktionsfaktoren wie Saatgut und Dünger.

China verfügt über wenig Ackerland pro Kopf. Die Landwirtschaft versucht dies mit höheren Erträgen und verstärktem Einsatz von Arbeitskräften, Dünger und Pflanzenschutzmitteln zu kompensieren. Während der vergangenen Jahren ist der Einsatz von Produktionsmitteln weiter angestiegen und es ist sehr wahrscheinlich, dass sich dieser Trend fortsetzen wird, vorausgesetzt die chinesische Wirtschaft wächst weiter.

Eine Querschnittsanalyse der chinesischen Landwirtschaft zeigt, das diejenigen Bauern am meisten Pflanzenschutzmittel einsetzten, die Kulturen Anbauen, welche das höchste Einkommen pro Anbaufläche ermöglichen und wo am meisten in Produktionsmittel investiert wird. Daraus folgt, dass fortgesetztes Wirtschaftswachsum und eine weitere Öffnung der Agrarmärkte in Kombination mit einem Festhalten der Regierung and an der Selbstversorgungspolitik die Bereitschaft der Bauern Pflanzenschutzmittel einzusetzen erhöhen wird.

Sommaire

Au cours des deux dernières décennies, la Chine a connu un immense développent économique, des réformes institutionnelles profondes et une transformation fondamentale de la société. Ainsi, les agriculteurs sont devenus des entrepreneurs indépendants et des marchés libres pour les produits agricoles et pour les inputs ont commencé à se former.

Des changements dans les habitudes de consommation et l'ouverture des marchés ont orienté la production de l'agriculture chinoise vers des secteurs avec des avantages comparatifs. De ce fait, la production de céréales a baissé en faveur de "cash crops" intensifs en main d'œuvre comme les fruits et légumes. En vue de rester autosuffisant en céréales, le gouvernement chinois continue à intervenir dans la commercialisation des céréales et contrôle la production et la distribution de semences et d'engrais.

A cause de la grande densité d'habitant par surface cultivable, la Chine est forcée de produire des récoltes de haut niveau et emploie relativement beaucoup de mains d'œuvre, d'engrais et de pesticides. L'utilisation d'inputs a encore augmenté ces dernières années et il est probable que cette tendance se confirmera à l'avenir si l'économie du pays continue à grandir.

Une analyse transversale de l'agriculture chinoise démontre que les plus grandes quantités de pesticide sont utilisées dans les fermes avec les cultures rapportant le plus par surface et dans celles avec les plus grandes intensités d'investissements. Cela permet de conclure que la croissance économique et l'ouverture des marchés des produits agricoles accompagnée par la politique d'autosuffisance du gouvernement vont continuer à accélérer la propension des agriculteurs à employer encore plus de pesticides.

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Acronyms and Definitions

CCP	=	Chinese Communist Party
Grain	=	Chinese definition: cereals, tuber crops, and soybean
GVAO	=	Gross Value of Agricultural Output, value of farming, forestry, animal husbandry, and fishery
HRS	=	Household Responsibility System
Mule, 1 mu	=	0.0667 ha
SOE	=	State Owned Enterprise
SSB	=	State Statistical Bureau
TFP	=	Total factor productivity (Factor Productivity)
TVEs	=	Township and Village Enterprise
Yuan	=	Chinese Currency, 1 Yuan = 0.12 USD (April 21 2003)

Introduction

During the past decade, China has had one of the fastest growing economies in the world. Since it has an enormous potential in terms of production and consumer demand, its influence on both world markets and international politics will increase substantially as its economic growth continues. Chinese efforts towards membership of the World Trade Organization will support this trend.

In the face of a rapidly growing population and the effects of several famines in the late 1960s, the Chinese government gave agricultural development the highest priority. This has influenced the development of agricultural production ever since. Technological improvements and promotion (e.g. research and extension) together with infrastructure development (e.g. irrigation) have been combined with the introduction of several reform measures designed to improve incentives to farmers.

Continued economic growth and market development have led to an increase in urban incomes which have induced an increase and change in food demand. Although urbanization has accelerated, a high proportion of the Chinese population still relies on agricultural production. Despite some income increases in the agricultural sector, the income-gap in relation to the non-agricultural sector has widened dramatically during the last few years.

Comparing Chinese agriculture with other countries, it can be stated that it operates on a high-yield level and that there is a relatively high use of labor, fertilizers and pesticides. Comparative cost advantages, therefore, lie in labor-intensive products such as vegetables and fruits. However, in order to keep the country self-sufficient, government policy continues to enforce grain production, thus preventing farmers from producing at an optimum level.

Obviously, Chinese farmers live in one of the world's most dynamic countries, in which economic and institutional conditions are still changing. Being the most populous country of the world, any change in food supply will affect millions of people. Due to the vast size of Chinese agricultural markets, even small changes have enormous consequences on the equilibrium of world markets.

The aim of this dissertation is to describe and understand the fundamental processes that have led to the current situation of Chinese agriculture and to be able to value the reach of different trends. The study focuses on the role of agricultural technology and the use of pesticides in particular. The dissertation consists of two parts:

Part I reviews the literature which is available to provide a comprehensive insight into the current situation of the Chinese crop sector and its environment. The work focusses on the economic relationship between Chinese farmers and the agricultural input and output markets, supplemented with the corresponding agricultural, political and historical background. Special emphasis is placed on the role of the seed and pesticides sector.

The first chapter is an introduction to China, discussing the development of the Chinese economy and its impact on Chinese food consumption, the natural environment and actual agricultural output. The second chapter deals with the changing institutional framework and ongoing reforms in agricultural markets. This is followed, in chapter three, by a discussion on Chinese input policy and the role of land, labor, irrigation and fertilizers in agricultural production. The next two chapters examine the situation of the Chinese seed and pesticides sector.

Part II examines the determinants of pesticides use, and how the ongoing dynamic change in China will affect pesticides use. Corresponding economic theory and related findings from Part one are confronted with the results of an analysis of Chinese farm household data.

The second part starts with a chapter on theory of pesticides use from a microeconomic perspective. Then the findings of the first part are examined in terms of their possible impact on pesticides use. The next chapter presents the empirical model with which available data were analyzed to find out the determinants of pesticides use. Then, hypotheses on the expected results of different variables are postulated. Finally, detailed results are presented and their possible impact on known trends are discussed.

Part I

Crop Farming in China: Technology Markets and Institutions

1 Preconditions of Chinese Agriculture

1.1. Economic Development

China's economic reform began successfully with the agricultural sector in the late 1970s. Its success led to further reforms, first in other sectors of the rural economy, later also in the urban economy.

In the mid-1980s, the government adopted bolder measures in the urban sector. These included double-track pricing, enterprise tax and wage reforms, banking and financial reforms, a revenue sharing system between central and local government and the opening of fourteen coastal cities in addition to the other, long-established special economic zones (Carter et al. 1996). The key strategy of these reforms involved a two-track approach: continuing government control over the government enterprise sector while a new, non-state sector was allowed to develop, largely outside state control (Sachs and Woo 1993). The reforms also helped to promote a higher degree of self-responsibility within the state system (Walder 1996).

Further reforms have taken place since 1988 with a view to promoting greater market orientation. Then, in 1992, the government officially announced its objective of leading the Chinese economic system towards a socialist market economy involving a market-orientated economy with less government involvement in economic activities (Carter et al. 1996). Today, China is undergoing a rapid transition from a socialist system to one in which an increasing proportion of its goods and services, including food, are allocated by market forces (Sicular 1995; Park and Rozelle 1996). In spite of this development, the government is still a major player in the economy and remains deeply involved in guiding the nation's development process (Huang J. et al. 1997).

Traditionally, urban and rural economies have been separate entities. As a result of this, integration of these two sectors of the economy is still inadequate. Key constraints include distorted prices, imperfect or non-existent markets and immobility of production factors. This also applies to intra-regional exchange between rural economies. Within an individual region, however, there is a strong link-up between agriculture and rural industry (Carter et al. 1996).

1.2. Changes in Food Consumption

From the 1950s through to the mid-1970s, consumption was kept artificially low by Mao's policy of self-sufficiency (Walker 1984). While rural consumers lived off their own production and bought various products at existing informal, local markets, the urban population's consumption was, to a large extent, controlled by the state food system, whereby urban consumers received food at cheap prices according to their ration allocations.

The reforms which started in 1978 led to a gradual liberalization of food markets. In the early 1980s, it became permissible to sell products that were surplus to the planned quantities in local markets. Later, these products could also be shipped by private traders for sale in urban areas. Starting with fruit, vegetables and surplus quota production, more and more goods were released from government control until, in 1993, the government finally attempted to abolish all price controls and the food stamp system in cities. Today, there are still some food stamp programs for the urban poor. The majority of products are, however, sold at market prices. Further see chapter 2.2 page 24 et sqq..

Economic development progressed concurrently with the development of food markets and led to a rise in incomes which allowed the population to increase their spending on food. Urban incomes rose by nearly 8 percent in the early years of reform and the demand for almost all food products also rose accordingly. The continued rise in incomes between 1985 and 1992 (average: 7 percent per year) led to a marked increase in meat consumption; on the other hand, there was only a slight rise in food-grain consumption (Huang J. et al. 1997). At the same time, urban residents were also turning to the free markets in search of better quality food (Carter et al. 1996). Changes in the urban economy have made urban consumers almost entirely dependent on the market for their consumption needs. Market prices and changes in income are probably the fundamental forces generating changes in consumption patterns. In addition, consumption patterns will be influenced by the further development of markets and increased activity in rural consumer markets (Huang J. et al. 1997).

Although rural incomes have increased since the mid-1980s, they have risen much more slowly than those in urban areas. However, the demand for food grain and meat products has also risen. It must be said that rural markets are less complete. The main reasons for this include discontinuous free markets, lack of refrigeration and generally high transaction costs for food procurement in rural areas. As a result, rural consumers' choice is limited and only 46 percent of the food consumed in these areas comes from markets; while self-sufficiency production continues to be the source of a considerable share (Huang J. et al. 1997). Fan et al (1994)[1] found that in rural areas consumption of all principal food commodities had risen simultaneously with expenditure. They found that rice, wheat and coarse grains are necessities, while meat, vegetables, alcohol and tobacco rate as luxuries. Expenditure elasticities for rice, coarse grains and tobacco tend to be declining, while those for wheat, meat, vegetables and alcohol are increasing.

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1 Applying a dynamic AIDS model, various rural food demand parameters were estimated using data from the household survey of the China Statistical Bureau.

Prior to 1978, China's rural economy exhibited 62.5 percent self-sufficiency in food production. This declined steadily in the following years to around 48 percent in 1980 and 36 percent in 1993 (Walker 1984). Han et al. 1998)[2] demonstrated that rural households which are not engaged in fruit and vegetable production for self-sufficiency purposes are much more income and price elastic in their consumption decisions than those which produce or sell certain products themselves. Furthermore, Huang J. and Rozelle (1995a) showed a marked and significant correlation between the level of consumption of goods primarily obtained by purchase, such as meat and fruit, and the level of market development.

The structure of Chinese society has changed significantly during the last two decades. Urban population rose from 19 percent in 1980 to 28 percent of the total population in 1992. It has been shown that urban dwellers throughout Asia change their consumption patterns independently of income and price levels. They consume more wheat and less rice and require more meat, fish and dairy products than their rural counterparts. Although cross-section analysis reveals that income elasticity of demand for rice is either close to zero or positive, per capita rice consumption has declined dramatically in Japan and Taiwan as the economy has undergone further development. This shows that not only income levels but also shifts in social structures, such as urbanization and daily habits, may exert considerable influence on food consumption. At the same time, an analogous demand for meat, fish and dairy products in Taiwan and Japan has also indicated correlation with urbanization (Huang J. et al. 1997).

Today, there are indications that Chinese food consumption is tending to reflect the behavior patterns of Taiwan and Japan. However, this does not necessarily mean that the high levels pertaining in these countries will be reached as incomes continue to rise in China. For example, there was no great decline in rice consumption in Korea between 1973 and 1992 in spite of the dramatic structural shifts which took place during that period (Huang J. and Bouis 1996). Furthermore, the population of Hong Kong still consumes less meat than the Taiwanese population (Ikegami 1997).

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2 Han et. al. 1998 applied a two-stage budgeting model to analyze fruit and vegetable consumption in rural China, distinguishing households producing and selling, producing and not selling, or not producing and not selling fruits and vegetables.

1.3. Agro Climatic Conditions and Agricultural Production

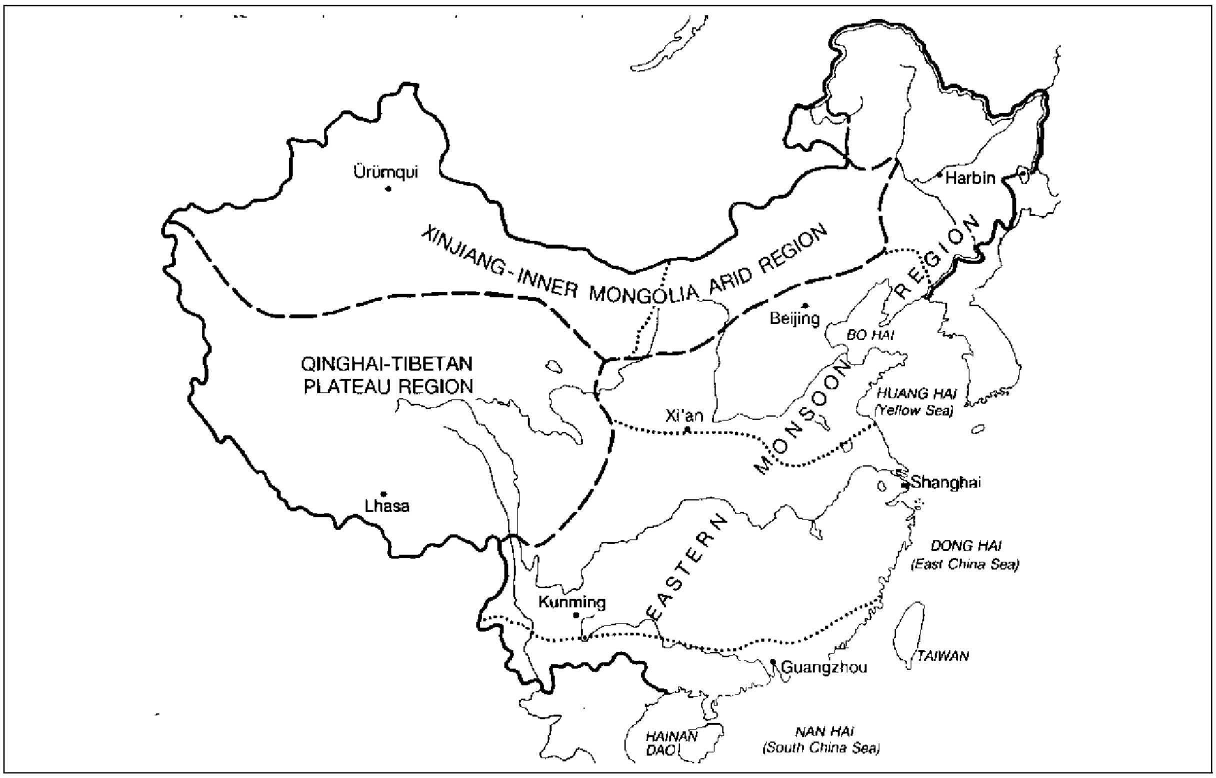

Figure 1-1: The Three Natural Geographic Regions of China

Source: Guohua and Peel 1991

China can be divided into three natural regions with physical features that differ significantly from each other, namely the Eastern Monsoon Region, the Xinjiang-Inner Mongolia Arid Region and the Qinghai-Tibetan Plateau.

The Xinjiang-Inner Mongolia Arid Region is part of the vast expanse of the central Eurasian desert and lies at an altitude of about 1000 m. It covers 30 percent of the total area of China but is inhabited by a mere 4 percent of the population. The region is extremely arid due to its great distance from the coast and the surrounding mountains. Agriculture is virtually impossible without irrigation.

The Qinghai-Tibetan Plateau is known as the “roof of the world”. It is the highest and largest plateau in the world, lying at an altitude of 4'000-5'000 m above sea level. This region constitutes 25 percent of the country's territory, though less than one percent of the population lives there. In both the Qinghai-Tibetan Plateau (Qinghai-Tibet) and the Xinjiang-Inner Mongolia Arid Regions (Gansu and Xinjiang, Inner Mongolia and areas along the Great Wall), animal husbandry is dominant.

Figure 1-2: The Agricultural Regions of China

Source: National Committee of Agricultural Regionalization 1981

The Eastern Monsoon Region is part of the much larger southern and eastern Asian Monsoon area. Over 50 percent of the world's population lives here. Although only forty-five percent of China's land is located within this region, it supports some 95 percent of the total population. The wet Monsoon in summer has a marked effect on the climate, the entire region being extremely humid. Irrespective of epoch, this area has been, is and always will be the country's principal agricultural region.

The western part of the Eastern Monsoon Region consists of the Loess Plateau in the north, the Sichuan Basin in the center and the Yunnan Guizhou Plateau in the south. The Loess Plateau and the Yunnan Guizhou Plateau lie at an altitude of 1000-2000 m above sea level, while the Sichuan Basin is only 250-700 m above sea level. The eastern section of the region lies below 200 m and consists of the plain of Northeast China, the North China Plain and the plains of the middle and lower reaches of the Yangtze River in the Southeast. An extensive range of hills with peaks rising to more than 1000 m lies to the south of the Yangtze River.

The region is subject to considerable climatic diversity: the further North the colder it becomes, while aridity increases with distance from the coast. The main crops change from maize, soybean and wheat in the North East to wheat, maize and cotton further south in the North China Plain, while rice is predominant in Southeastern and Southern China (Guohua and Peel 1991).

The Chinese Government has distinguished six major crop growing regions which are all located in the Eastern Monsoon Region: North East China, North China Plain, the Loess Plateau, the Middle and Lower Yangtze River Valley, Southwest China and South China. An overview of cropping activities as well as land and labor distribution is presented in Table 1-1. A detailed description of agricultural conditions in the main agricultural regions of China is given in chapter 9.1 page 155 et sqq.

Table 1-1: Total Production, Population and Sown Area by Region 1992-95 (in 1000 tons, ha or heads)

	Total	North-east	North China Plain	Loess Plateau	Lower Yangtze	Middle	South China	South-west	West-/ North-west
Grain[a]	452'717	8.8%	22.6%	6.3%	16.2%	14.6%	9.2%	13.7%	4.3%
Vegetable Oil[b]	8'736	9.3%	22.5%	4.1%	23.7%	13.8%	9.0%	8.4%	6.7%
Fiber[c]	28'849	3.4%	27.1%	15.7%	27.7%	4.1%	0.1%	10.7%	7.6%
Sugar[d]	7'172	6.4%	0.2%	2.8%	0.1%	2.8%	60.0%	19.2%	7.5%
Vegetables[e]	8'387	6.8%	20.8%	4.9%	13.9%	15.7%	19.1%	14.7%	1.9%
Fruit[f]	24'870	6.7%	33.1%	11.2%	8.9%	5.7%	22.6%	7.9%	3.5%
Meat[g]	40'974	8.3%	21.6%	4.3%	13.8%	16.4%	13.9%	18.2%	3.3%
Sown area[h]	148'717	11.0%	22.0%	9.0%	14.0%	14.0%	9.7%	14.5%	5.9%
Agr. Popul.[i]	901'835	6.3%	22.6%	8.1%	15.6%	13.9%	12.9%	17.2%	3.4%
Tot. Popul.[j]	1'170'102	8.6%	22.1%	7.9%	15.7%	13.6%	12.7%	15.6%	3.8%
Sa/Agr. Pop.	0.16	0.29	0.16	0.18	0.15	0.17	0.12	0.14	0.28
Sa/Tot. Pop.	0.13	0.16	0.13	0.14	0.11	0.13	0.10	0.12	0.19

[a]Total grains : all cereals in dry unprocessed weight, corn shelled, tuber crops 1/5 of the weight, soybeans and beans without pods; [b]edible vegetable oil: peanuts, rapeseed, sunflower seed, sesame seed, huma oils as well as oils from soybeans, rice bran, corn and cotton; [c]hemp, cotton, jute; [d]processed cane and beet sugar; [e]area sown with all vegetables and vegetable-type melons in 1000 ha; [f]apples, bananas, citrus fruit, grapes, pears; [g]beef, pork, mutton, poultry, rabbit; [h]in 1000 ha; [i+j]in 1000 persons

Source: USDA 1998, Mannlib Database

According to the 1997 data acquired from FAO statistics, Chinese farmers harvested crops on a total of 168 million hectares. More than half of this area was devoted to cereal production followed by oil crops, fiber crops, vegetables, roots and tubers, fruit and pulses. Viewed individually, the harvested areas show that rice, wheat and maize cover 52 percent of the total area. These crops also account for 93.6 percent of total area devoted to cereals. Cotton covers 99 percent of the total fiber area. In addition, soybeans, rapeseed and groundnuts cover the largest share (90%) of the total area under oilseed crops. Tubers are represented by sweet potatoes and Irish potatoes. Over two thirds of the harvested area came under the "grain" crops category i.e. cereals, soybean, tuber and pulses (FAO 1998).

Table 1-2: Harvested Area per Crop 1997

Crop	1000 ha	
Rice	31'348	18.7%
Wheat	30'000	17.9%
Maize	23'510	14.0%
Cotton	13'809	8.2%
Soybeans	8'505	5.1%
Rapeseed	6'380	3.8%
Sweet Potatoes	6'311	3.8%
Apples	3'701	2.2%
Groundnuts	3'634	2.2%
Potatoes	3'502	2.1%
Dry Beans	3'052	1.8%
Tobacco	1'884	1.1%
Drupac. Fruit	1'750	1.0%
Millet	1'600	1.0%
Barley	1'600	1.0%
Citrus Fruit	1'376	0.8%
Sorghum	1'213	0.7%
Pears	1'210	0.7%
Sugar Cane	1'103	0.7%
Broad Beans	1'000	0.6%
Watermelons	989	0.6%
Tea	900	0.5%
Other Crops	19'629	11.7%
Total	168'006	100%

Source: FAO Database 1998[3]

Table 1-3: Harvested Area per Crop Category 1997

Category	1000 ha	
Cereals	91'622	54.5%
Oil	20'780	12.4%
Fiber	14'192	8.4%
Vegetables	12'116	7.2%
Tuber	10'125	6.0%
Fruit	9'426	5.6%
Pulses	4'897	2.9%
Stimulants	2'807	1.7%
Sugar	1'662	1.0%
Nuts	275	0.2%
Spices	105	0.1%
Total	168'006	100%

Source: FAO Database 1998

3 The FAO divides plant production into twelve categories. Cereals include rice, wheat, maize, sorghum, millet, barley, rye, oats, buckwheat, triticale and others. Oilseed crops include soybeans, groundnuts, rapeseed, sesame seed, sunflower seed, linseed and others. Fiber crops are cotton, lint, jute, tow, ramie and others. Vegetables include all leaf and fruit vegetables as well as melons. Root and tuber crops are Irish potatoes, sweet potatoes, cassava, and taro. Stimulants are coffee, tea and tobacco. Sugar includes sugar beet and sugar cane. Pulses are beans, peas, lentils and others.

Between 1953 and 1995, the real value of aggregate agricultural output[4] grew at a compound rate of 3.9 percent per year. Up until 1978, growth only amounted to 2.6 percent and then increased to an average of 5.8 percent per annum from 1979 to 1995. In the early years of the Peoples' Republic of China, agriculture grew steadily until the late 1950s. The promotion of large scale production and the establishment of the communal system led to a sharp decline in output. A series of adjustments allowed production to recover and growth continued until the mid-1960s when it was once again depressed by inappropriate policies. Although the initial reform measures boosted agricultural growth to 6.7 percent per year from 1979 to 1984, the sector was adversely influenced by policies implemented between 1984 and '88 which led to a decline in growth rate to 2.5 percent per year. After 1988, agriculture recovered to a certain degree and reached an annual growth rate of 7 percent between 1989 and 95 (Fan 1997).

The reforms of 1978 allowed some diversification in the farming sector. Decentralization of production decision-making encouraged farmers to focus on specialized, commercial production. Agricultural production, therefore, developed in line with the sector's comparative advantages. This led to significant structural changes in agricultural production. From 1978-94, fishery increased almost fourfold in real terms and animal production doubled (in size), while the crop sector grew by 55 percent. In 1978, cropping accounted for 80 percent of the gross value of agricultural output (GVAO), but declined to 58 percent by 1994.

Within the cropping sector, there was a shift towards more labor-intensive crops and the production of goods for sale at regional markets increased dramatically (Carter et al. 1996). Table 1-4 illustrates the development of crop production during the period 1981 to 1997. It can be seen at a glance that the production of crops promoted and regulated by the government, such as cereals and fiber, increased much less than that of crops whose markets were liberalized in the 1980s. While production of fruit, vegetables and stimulants grew more than 8 percent per year, cereals increased by only 3 percent and fiber by a mere 4 percent. Production of vegetable oil and pulses stagnated with an average growth rate of 0.8 percent or below.

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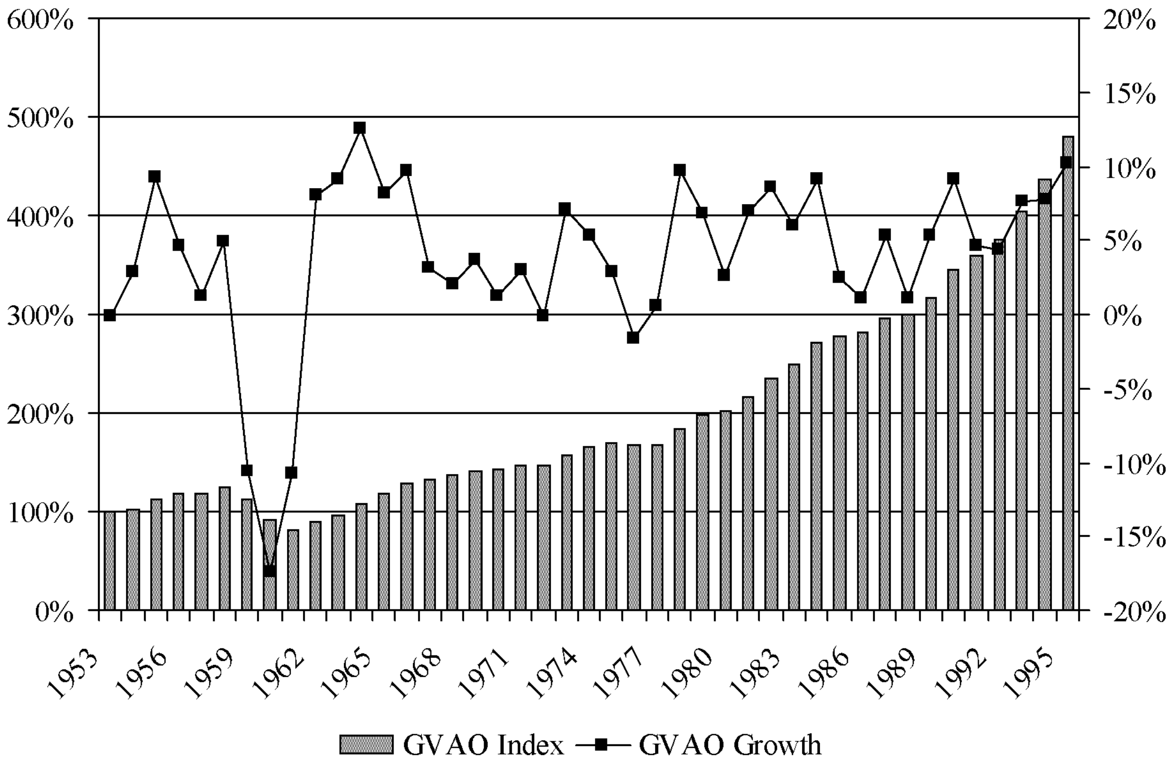
[4] Fan (1997) calculated the Thörnqvist-Theil Index of the aggregate agricultural production. Using constant prices for comparison over years can lead to biased results as price relations between products are assumed to be constant although they usually change over time. In order to minimize this bias changes in aggregate production can be adjusted by the Thörnqvist-Theil index (a discrete approximation of the continuous divisa index).



GVAO index is the Gross Value of Agricultural Output, expressed by the Thörnqvist-Theil Index, whereby 1953 is 100 percent

Figure 1-3: Production Growth in Chinese Agriculture 1978-95

Source: Fan 1997

With the exception of the famine years, i.e. the late 1950s and early 1960s, the country enjoyed growth rates in the grain[5] production sector that outpaced the rise in population. Even between 1970 and 1978, when much of the economy was suffering from the effects of the Cultural Revolution, grain production grew at 2.8 percent per annum (Huang J. et al. 1997). Since the mid-1980s, growth in the grain economy has fallen below the average growth rate of the 1960s and 1970s. However, it is still positive (Huang J. et al. 1996).

[5] According to Chinese statistics "grain" includes all cereals as well as soybean, root and tuber crops and pulses.

Table 1-4: Annual Growth According of Crop Categories and Population Growth 1981-97

	1981-84	1985-88	1989-92	1993-97	1981-97
Fruit	8.60%	13.42%	8.81%	14.92%	11.64%
Vegetables	12.08%	9.45%	4.26%	10.23%	9.08%
Stimulants	15.28%	10.87%	6.08%	3.56%	8.63%
Sugar	10.36%	3.77%	10.84%	-0.57%	5.71%
Fiber	20.58%	-5.44%	1.11%	0.91%	4.09%
Spices	4.91%	4.80%	2.86%	2.29%	3.63%
Cereals	7.01%	-0.88%	3.67%	2.20%	2.95%
Nuts	-1.53%	6.68%	1.06%	4.76%	2.86%
Pulses	-1.39%	-0.74%	-16.52%	17.65%	0.81%
Tubers	-0.01%	-1.22%	1.34%	2.63%	0.80%
Vegetable Oil	1.29%	-2.59%	2.84%	0.28%	0.45%
Population	1.37%	1.56%	1.35%	1.00%	1.30%

Sugar: centrifuged raw sugar; oil: processed vegetable oil; stimulants: average of the production of tea, tobacco, coffee in percentages of 1980; other categories: aggregate quantities

Source: FAO Stat 1998

Summary

Between the founding of the People's Republic of China and 1978, Chinese economic strategy was designed to promote economic development within a planned framework, whereby all economic activities were run by the State or collectively owned enterprises. This strategy changed in the late 1970s. Starting with agricultural production, sections of the economy were gradually allowed to assume responsibility for their operations and markets gained in importance. Combined with massive foreign investments in the 1990s, the economy has grown substantially during the past decade. New employment opportunities and rising wages have transformed the entire society. However, the government is still heavily involved in economic activities and market interventions.

Over the last ten years, the development of food markets and rising incomes have generated significant changes in food consumption. In the first place, rising incomes resulted in an increase in overall food demand, while growing urban populations have led to higher wheat, meat, fish and milk consumption. On the other hand, rice consumption is stagnating. In rural areas, self-sufficiency declined from 62 percent in 1980 to 36 percent in 1993 and higher incomes have also enhanced consumption of meat and vegetables. However, average incomes are low and a large share of the population lives in rural areas. Ongoing changes in incomes and structures are likely to bring about further shifts in consumption patterns.

In 1997, the total crop area harvested was 168 mil. ha., of which two thirds were used for "grain" production i.e. cereals, tubers and soybean. Up until 1978, the annual growth of the gross value of agricultural production, i.e. crops, animal production and fisheries, grew by an average of 2.6 percent and jumped to 5.8 percent between 1978 and 1995. The reforms of 1978 allowed a diversification of agriculture. In consequence, the growth of animal production and fisheries pushed cropping down from 80 percent of Gross Value of Agricultural Output in 1978 to 58 percent in 1995. Within the crop sector, there was a shift towards the production of fruit, vegetables, tea and coffee. Although the growth rate for grain production was higher before 1978, it remained positive in the 1980s and 1990s, still being twice as high as population growth.

2 Agricultural and Agricultural Trade Policy Under Reform

2.1 Reform of Rural Institutions

2.1.1 Collectivization of Chinese Agriculture

a. Land Reform and Abolition of Feudalism 1949-52

In 1949, over 70 percent of the rural population were smallholders and agricultural laborers. The majority of these smallholders were tenant farmers who were usually obliged to rent land at exorbitant rates, amounting to as much as 70 percent of their annual yield, paid in advance. 70 to 80 percent of the land under cultivation was owned by a mere 10 percent of the rural population (Kirsch et al. 1994; Fan and Pardey 1995).

In the course of the reforms of 1949, 45 percent of the total area under cultivation was redistributed to 60 million smallholder families, landless peasants and landless laborers. This was achieved at the expense of 4 million landlords whose land was confiscated completely and 'rich peasants' who were dispossessed of part of their property. Draught animals and agricultural implements were also redistributed.

This redistribution of land did not create equal starting conditions for the rural population as a whole. Production success varied in line with management experience and differing access to capital. The selling and leasing of land was still possible. Following the reforms in the early 1950s, farmers could be divided into three classes: poor peasants with 15 percent of the total land and an average farm size of 0.84 ha; middle-class peasants with 80 percent of total land and an average farm size of 0.93ha; rich peasants with 15 percent of total land and an average farm size of 1.22 ha.

The implementation of the reforms led to the social, and in some cases physical, elimination of the former ruling class in the villages. They were replaced by a class of political and technocratic leaders. At this stage, the Chinese Communist Party encouraged the establishment of Farmers' Associations on a voluntary basis. These consisted mainly of smallholders and workers, although middle-class peasants were also accepted (Kirsch et al. 1994).

b. Collectivization of the Means of Production 1953-1956

In 1952, some poor smallholders and middle-class peasants realized that their scale of production was too small for certain agricultural operations. To counter this, they voluntarily pooled their land and other resources to create so-called "Mutual Aid Teams", a co-operative mode of operation comprising 6 to 15 families per group. Membership was voluntary with free enrolment and resignation. Some farming operations were organized jointly while the yield taken off a farmer's land was used individually (Kirsch et al. 1994; Fan 1997).

1953 saw the establishment of "Elementary Producers' Co-operatives". These consisted of 30-60 families and corresponded to the size of a natural village. In these early co-operatives, land cultivation and titles were transferred to the co-operatives. Land value was regarded as the share capital. Means of production, such as farm implements and draught animals, were either sold to the co-operative or put at its disposal without compensation. The members of the co-operatives worked under common administration and planning, whereby the fields were cultivated jointly by the agricultural co-operative enterprise. Members received payment according to the land donated (30%) and the labor performed based on the number of days worked or according to work points. This collectivization took place in several stages, starting on a voluntary basis and finally becoming compulsory.

"Advanced Agricultural Producers' Co-operatives" were founded from 1955 onwards. They were the result of a merger of several Elementary Producers' Co-operatives. Initially they comprised 70-80 families, and later on up to 200-300 families, per unit. This form of co-operative was, by definition, totally collectivized as all means of production were transferred to the co-operative. Private land ownership was completely abolished and private land use limited to small plots or kitchen gardens constituting about 5 percent of all arable land at that time. Members were paid exclusively according to the labor they performed (Kirsch et al. 1994). By 1957, this form of co-operative was established on a virtually nation-wide basis. Since the Advanced Agricultural Producers' Co-operatives were larger than a village, natural villages were transformed into larger administrative villages in keeping with the co-operatives.

The rest of the economy was also collectivized concurrently with the establishment of the Advanced Agricultural Producers' Co-operatives. In addition to the state agricultural credit bank, each township (administrative district) established its own credit co-operative society, offering unbureaucratic production loans. The state assumed control over rural trade by establishing state-run marketing co-operative societies. Retail shops selling agricultural implements or special consumer goods were transformed into co-operatives or mixed-economy type enterprises. Private businesses in the craft and transport sector amalgamated to form co-operative societies. Modern transport, such as railways, and the mail service were nationalized or transformed into mixed-economy type enterprises (Kirsch et al. 1994).

c. Period of the People's Commune 1957- 1977

Within a period of just two months in the year 1958, the 740'000 Agricultural Producers' Co-operatives were merged to form some 25'000 People's Communes comprising an average of 4'600 people per commune. From now on, all land was collectively owned - even private plots were collectivized.

The Communes were responsible not only for production but also for political matters, as the former village administration, too, was absorbed into the People's Communes. As a result of this, all existing rural institutions were reorganized into the People's Communes leading to a 30-fold increase in the scale of the organizations. This single institution had to deal with local administration, agricultural organization and other non-agricultural production activities, such as trade organization, control of all means of production, education, local militia force and social services.

The resistance mounted by the peasants, the over-zealousness of the cadres and natural disasters all combined to bring about the so-called "three bitter years" (1959-61) of famine and economic set-backs that followed. In consequence, the Communes had to be readjusted, as early as 1959, into smaller cultivation and accounting sub-units called Production Brigades, consisting of the former administrative villages or Advanced Agricultural Producers' Co-operatives. Production Teams, the existing sub-units of the former co-operatives, were restored within these Production Brigades. These Teams corresponded to the size of an original natural village with 20 to 30 neighboring families. In addition, private plots were returned to the farmers. Huge communes were divided up, which meant that their number tripled from 25'000 to 75'000.

In the course of 1961, the Production Teams were assigned responsibility for production and accounting. Indeed, an experimental kind of "responsibility system" (see next Chapter) was introduced in some Communes. The system was simple and attractive for the farmers, but the relationship between team members resembled the old landlord-tenant rapport.

When the Cultural Revolution got under way in 1966, a new attempt was made to transfer ownership from the lower-level Production Brigade to the higher-level People's Communes. Small private plots had to be returned to the People's Communes, although they were restored in 1971 due to the massive resistance mounted by the peasants. Ownership was now formally re-established at three levels: Commune, Production Brigade and Production Team.

President Nixon's visit in 1973 strengthened the influence of the reformers. Private plots or kitchen gardens were reintroduced and Production Brigades were empowered to do their own accounting and were given the responsibility for distributing incomes and surpluses, as well as for the independent planning of production and investment (Kirsch et al. 1994).

d. Institutions and Structure of People's Communes

A typical commune consisted of ten to fifteen production brigades. Each brigade was sub-divided into about ten production teams consisting of twenty to thirty households. The commune was both a government body and a compulsory co-operative. It implemented directives from higher levels of government and managed small-scale enterprises and shops. The brigades not only passed down directives and allocated quotas but also ran primary schools, clinics and shops. The production teams, the basic unit of the organization, were responsible for agricultural production, accounting and income distribution (Carter et al. 1996). A party committee represented the Communist Party's interests in the executive branch at all three levels (Kirsch et al. 1994).

These three levels, the Commune, Production Brigade and Production Team owned some of the collectivized equipment and enterprises which were allocated according to their responsibilities. The Commune owned those means of production which were not managed by the Brigades and Production Teams, either because they were too big or their organization was too complex. These included larger industrial enterprises and workshops, heavy machinery, means of transport, local credit departments and marketing co-operatives, as well as social services such as schools, hospitals and agri-technical stations. The Brigades owned smaller enterprises which were too big to be run by Production Teams. These included small scale industries, workshops and machines. The means of production owned by a Team corresponded to its production capacity in terms of land, buildings, smaller machines and tools, draught animals and small commercial enterprises (Kirsch et al. 1994). In 1978, 95.7 percent of total cultivated land belonged to the Production Teams, 3 percent to the Production Brigades and 1.1 percent to the Communes (Gu 1993). 5-15 percent of the total cultivated land was allotted to farmers as family plots. There were no markets for land and other resources.

The only exception to this involved rural land requisitioned for urban, industrial purposes. The Communes received financial compensation for the transfer of part of their land, albeit at a rather low price (Huang X. et al. 1998).

In the main, Communes and Production Brigades received an income from their enterprises and service units. Contributions from Production Teams to accumulation funds represented another source of income. This income had to cover the payment of taxes, the performance of certain functions on behalf of the government and the contribution of collective labor for public works and infrastructure. Production Teams' incomes were derived from the sale of produce to government marketing agencies and from the co-operative organizations. 29 percent of this income was assigned to the Commune for public purposes[1] while the remaining funds were used to remunerate the team members (Kirsch et al. 1994).

The method of calculating team members' salaries changed several times during the era of the People's Communes. In the initial period just after the Communes were founded, farmers were paid according to their achievements, giving due consideration to the type of work and working conditions. Later the system

[1] 15% taxes, 12 % accumulation fund for investments and social services, 1% administrative expenses.

was altered to a so-called common work-point system, under which members were allocated a fixed number of basic points per working day according to their qualifications. This was again changed to a time/rate system based on specific norms for different kinds of work. Prior to the Cultural Revolution, a contract and piecework system was temporarily in force (Kirsch et al. 1994). The working-point system called "learning from Dazhai" was introduced as per 1965. The philosophy behind this system was the socialist principle of putting public interest first. Finally, a fixed-rate flexible-assessment scheme was imposed under the terms of which Production Team members were classified according to criteria such as strength, skills, diligence, working attitude and political awareness.

2.1.2 Reform of Rural Institutions

a. The Household Responsibility System

The poor performance of the agricultural sector during the two previous decades persuaded central government to reform the rural areas in 1978. Initially, the intention was to stimulate production within the existing social framework. However, the great success of the measures encouraged the government to adopt bolder reforms and finally led to the transformation of the whole economy into a "socialist market economy". The whole reform program, indeed, was never planned as a comprehensive policy. It was more a case of one step following the next under the influence of current events (Carter et al. 1996).

The Household Responsibility System (HRS) was a type of farming whereby property rights were divided between ownership (by the village) and management (by the households). Farmers had a contract with the local authorities which defined land-use rights, production and procurement quotas and, in some cases, part of the fixed assets of the production teams for individual households. The individual farmer was allowed to keep what remained after fulfilling his quota obligations and submitting a certain amount of total output or revenue to the team (Carter et al. 1996). The introduction of the Household Responsibility System (HRS) was designed to return land usufruct rights to individual farmers and change collective labor into household management. Consequently, farmers' remuneration became closely linked to their labor and land output. In this way, the "free-rider" problem which had arisen under other salary systems was solved to a large extent (Huang X. et al. 1998).

In 1978, a form of HRS was secretly adopted by farmers in some locations in Anhui province. Initially, the government insisted on collectively managed farming but reluctantly accepted the Household Responsibility System two years later as an inevitable measure in poor, remote and mountainous regions, or in places where farmers had lost all confidence in collective management. Subsequently, policy changed rapidly when it became clear that the Household Responsibility System was a highly successful means of increasing agricultural production and it spread all over the country. By 1981-82, the HRS was openly encouraged and almost all production units had adopted the new system by 1984 (Carter et al. 1996).

Under the HRS, land plots were usually allocated to households on the basis of household size, soil quality and distance from the dwelling. Changes in population composition led to the reallocation of land. Initially, land contracts were usually valid for only one to three years. This was extended to fifteen years and more in 1984 (Ash 1993). Given the high person-to-land ratio, this method of land distribution generally resulted in small, fragmented patches of farmland (Zen 1991) with an average of 0.56 ha of arable land per household divided into 9.7 parcels of an average size of 0.06 ha. This fragmentation closely resembled the situation in the 1930s, when an average of 0.34ha of land was divided into 5.6 parcels per household (Buck 1938; Huang X. et al. 1998).

Land usufruct underwent further extension during the period 1993-98. The new land contracts were extended for another 30 years with a view to ensuring the stability of the HRS. From this time on, land was no longer subject to reallocation when the size of the household changed. In addition, contracted land could be transferred to other farmers against compensation (Huang X. et al. 1998), the purpose of this measure being to increase the size of the farm and improve the productivity of land and labor.

b. Dismantling of the Communes in 1985

In 1982, Communes started to implement measures to split up their former administrative and economic functions and re-establish township governments. A new institutional framework was set up consisting of three levels: township (xiang), village (cun), and production team (cunmin xiaozu). The townships and villages took over some of the functions that had previously been fulfilled by the Communes and Production Brigades. From a formal point of view, townships and villages became government and administrative bodies. However, they also acted as managers of the collective property left after the communal system and assumed responsibility for primary and high school education and basic health care within their jurisdiction (Carter et al. 1996). Procurement quotas, taxes and other obligations to the state and local government were allocated to townships and villages according to farm size and family size (Ash 1993).

In 1993, a township comprised an average of 4770 households (SSB RSY 1994). At this level, the party committee was in control and the township government dealt with routine administrative duties. The head of the township government was usually a member of the party committee. The township government allocated procurement quotas, enforced the implementation of quotas and the collection of taxes, supervised the management of municipal enterprises and provided hospitals and high schools. The average village consisted of 286 households (1993), i.e. roughly the same size as the former Production Brigades. A branch of the township party committee was in charge of the village (Carter et al. 1996).

The functions of a village committee resembled those of the township government but on a smaller scale. They included: management of village enterprises, provision of health clinics and elementary schools. They also ran some co-operatives. In recent times, villages have begun to play a greater role in agricultural production by providing certain types of farming services under contract with individual farmers. In Southern China, Township and Village Enterprises still continue to act as water allocation managers or coordinators and hence as informal production planners for irrigated crops.

The Cunmin Xiaozu represented the level of the former Production Team and consisted of about twenty to thirty households. They officially owned the land, contracted out land-use rights to individual households and passed on a share of the mandatory procurement quota to the households. They were also responsible for distributing tax obligations to each household (Carter et al. 1996).

c. Development of Township and Village Enterprises

In order to enhance the character of self-sufficiency in the rural People's Commune, small-scale enterprises and shops were established and run by the Communes and Brigades. These enterprises were engaged mainly in processing farm products and by-products, and in providing technical services. The Cultural Revolution provided an opportunity for these "Commune and Brigade enterprises" to expand their production and change the scope of their operations. However, due to stringent government regulations, they were not able to develop as rapidly as they would have liked.

After the abolition of the Communes, these enterprises were run by the villages and townships. Government policy towards these so-called Township and Village Enterprises (TVEs) underwent a change at that time. They were seen as a potential source of off-farm income for farmers, a provider of subsidies for social welfare programs and a channel for absorbing excess agricultural labor. The government encouraged TVEs by granting tax reductions and planned loans from state banks at low interest rates.

Stimulated by the changes in agricultural policy in 1978, the economic growth of the TVEs exceeded all expectations. Following the 1978 economic reforms, the value of industrial output generated by the TVEs increased rapidly with an average annual real growth rate of 15.3 percent from 1978 to 1992. This was approximately double that exhibited by urban State-owned enterprises (SOEs) or the agricultural sector. In 1978, the TVEs' share of rural output value was 24.3 percent. It had increased to 66 percent by 1992. This represented 32 percent of total Chinese output in 1993. The TVEs' share of rural employment more than doubled between 1978 and 1985, indicating that the development of the TVEs had indeed absorbed a large share of rural labor. After experiencing rapid growth in the early 1980s, the growth of the TVEs and their absorption of labor slowed down in the latter part of the decade, only to accelerate again in the early 1990s (Carter et al. 1996).

The TVEs have helped to maintain agricultural production by means of a certain degree of direct cross-subsidization, the provision of technical services and the development of infrastructure at community level. In addition, they have mitigated the problem of surplus rural labor and the flight of workers to cities (Chen et al. 1992). On the other hand, upcoming TVEs have started to compete with the agricultural sector for production factors. As a rule, TVEs employ workers from among the best educated villagers, leaving farming to the elderly and women. For example, in some places in Southeast China, agricultural output has decreased due to a lack of skilled labor. Development has also led to a widening gap in personal incomes in rural areas (Islam 1991) and has created serious pollution problems affecting agricultural land and water (Findlay et al. 1994). Efforts to establish TVEs in remote areas, such as the central and western part of the country, have often resulted in heavy financial losses (Carter et al. 1996) due mainly to poor infrastructure and inappropriate policies.

TVEs were the first to bring competitive pressure to bear on the urban State Owned Enterprises (SOEs), in that they also competed for inputs. Since the government has always favored urban areas, allocations of preferential credits and state controlled inputs have generally been biased against TVEs and in favor of SOEs. The mid-1980s saw an increase in the competitive pressure exerted by the TVEs as a result of new competition from private joint ventures (Chen et al. 1992) At the same time, the SOEs were called upon to assume responsibility for their economic performance (Koo et al. 1993). However, various studies revealed that TVEs could still compete thanks to the fact that their total productivity factor was over double that of SOEs.

On the other hand, from a long-term point of view, the small-scale structure of TVEs was not cost efficient. They were scattered over vast areas and thus required larger investments in transportation and infrastructure facilities, as well as incurring higher shipping costs for their inputs and outputs.

In response to this situation, some TVEs started to improve their technology by increasing their use of capital instead of employing a larger work-force. This development, combined with the fact that the economically better developed provinces enjoy a far higher degree of success, casts doubts upon the ability of TVEs to continue absorbing rural labor forces in the foreseeable future (Carter et al. 1996).

2.2 Market Policy Under Reform

2.2.1 Overview of Domestic Food Market Policy

Over the past fifty years, Chinese domestic food market policy has undergone far-reaching changes. The situation where markets for all products were under stringent government control changed after 1978 and more and more products were released for distribution on free markets. However, the government has maintained its control over markets for products considered to be of strategic importance. The following chapter gives a brief overview of market development and policy over the past decades.

a. Market Policy Prior to the 1978 Reforms

In November 1953, the communist government introduced production control together with a compulsory procurement program, urban quantity rationing and an administered pricing system (Fan and Pardey 1995).

A total state monopoly was established, beginning with grain[2] (Kirsch et al. 1994). With the emergence of the Peoples' Communes, the government established a monopolistic-monopsonistic procurement and marketing system for most agricultural outputs and inputs and centralized sown-area plans came into force. From that moment on, virtually all commodities were subject to various procurement programs which can be classified according to the degree of regulation involved: Unified Procurement (Tong Gou), Imposed Purchase (Pai Gou) and No Quotas.

The Unified Procurement system was applied to grain, oil-bearing crops and cotton with the government as the sole buyer of these crops. The procurement program was divided into a "basic quota" and "above quota" component. Basic quotas were fixed for a three- to five-year period, along with production targets and at fixed prices. The quantities for above-quota deliveries were also compulsory and fixed as a certain percentage of the production exceeding the basic quota. The so-called "premium above the quota price" paid was usually 20 to 30 percent higher. Production exceeding the above-quota level could be sold to the government at a "negotiation price" likewise set by the government.

The "Imposed Purchase" category consisted of meat and aquatic products, tobacco, tea, silk and sugar crops. The government set compulsory procurement quotas and corresponding prices for these products (Carter et al. 1996).

Above quota production could be sold on free markets. Vegetables and fruit were not subject to any quota obligations at all. However, producers were not allowed to engage in long-distance trading which meant that government agencies had overall power with regard to the marketing of these goods. To a large extent, they were in a position to fix prices, especially on industrial crops (Carter et al. 1996).

b. Step by Step Liberalization Since 1978

In 1978, existing free markets were legalized and private trade became permissible for some controlled products, for production exceeding the quota obligation and for private plot production. In addition, private long-distance shipping and marketing gradually became permissible. This gave farmers an opportunity to sell their surplus goods and free markets started to develop nationwide.

[2] i.e. cereals, tuber crops and soybeans

The reintroduction of household farming meant that production plans could no longer be enforced directly. Procurement and price policy therefore became the government's principal tools for maintaining its control over the production behavior of the farmers. Procurement prices for grain and other products were raised as an incentive to farmers to increase their production. While markets for fruit, vegetables and meat began to develop in the early 1980s, markets for grain and cotton continued to be highly regulated.

In 1985, the government converted the procurement system into a so-called "contracted purchasing system", whereby farmers were called upon to sign a contract with the government. As the quota was not met in 1985, these contracts became compulsory in 1986 (Carter et al. 1996). In the same year, several products were released for sale on free markets, reducing the number products under government control from 113 to 38 (Fan 1997). With these reforms, market forces slowly took their place in the resource allocation process. In 1987, the government reformed the markets for vegetables, fruit and fishery products. The number of commodities subject to government procurement programs now declined from 38 in 1985 to 9 in 1991. However, price control was retained for farm products of particular importance.

In 1985, the elimination of procurement and retail prices fixed by the government for fruit, vegetables, livestock products and other agricultural goods encouraged farmers to expand their production. From that time on, the production of fruit, vegetables and livestock products developed rapidly and growers benefited from the floating prices.

In 1996, agricultural products were still subject to various forms of government influence. Cotton production was still completely subject to compulsory procurement and the government had overall control of its marketing. On the other hand, once producers had fulfilled their quota delivery obligations, rice, wheat, corn and sorghum could be sold on the free market. It must be mentioned that quota prices was still fixed at artificially low levels. At the same time meat, aquatic products, edible oil, tea, silk, sugar, fruit, vegetables, some grains (potatoes, sorghum, barley, millet, peas, beans and oats) and other industrial crops had been released and could be traded freely throughout the country (Carter et al. 1996).

2.2.2 Grain Market

a. Overview

In order to understand Chinese agricultural policy, one must first understand its grain policy. From the founding of the People's Republic of China and up to the present day, the main objective of Chinese agricultural policy has been to provide urban consumers with adequate supplies of cheap grain. Fundamentally, every agricultural policy measure, applied at whatever level of the Chinese food market chain, has been aimed at achieving this goal. Grain production obligations were an integral part of the institutional framework of the People's Communes and the Household Responsibility System introduced in 1978. High investments in input industries, agricultural research and infrastructure helped to increase yields. In turn, grain was purchased at low prices by the state grain monopoly and transferred to the urban consumers. However, although they benefited from cheap grain, their allocations were rationed due to inadequate supplies. Finally, the Houko system was introduced forbidding rural citizens to settle in urban areas. The one child policy was yet another a measure designed to limit the increasing numbers of urban consumers.

After 1978, several attempts were made to release grain distribution to the free market. However, the government continued to keep its tight control over the grain market. This chapter discusses the development and dilemmas of Chinese grain marketing policy (Carter et al. 1996).

China's grain distribution system was established under a planned economic structure. The purpose of the marketing system was to ensure ample supplies of grain for urban residents at low prices fixed by the government. To this end, grain bureaux and associated agencies were set up at different government levels and authorized to handle the business of buying and selling grain. To a large extent, the government subsidizes the operation of the system. Due to complete market control, the running of these state marketing enterprises generally involved very few risks and the system seemed to function smoothly. However, when the government decided gradually to open the market, the system exhibited adjustment difficulties (Tuan and Cheng 1999).

b. Unified Procurement

Up until 1978, grain marketing was governed by the "unified procurement system" i.e. the government had a complete monopoly on the marketing of these crops which enabled it to fix prices administratively. Under this system, production quotas had to be delivered in accordance with Communes' production targets. The first share of the quota was reimbursed at the lower "basic quota price" and the remainder at the "above quota price" which was 20 to 30 percent higher. Production exceeding the production quota was purchased at a "negotiated price". Basically, the amount of "basic quota" purchases remained stable since 1953, leading to a steady increase in deliveries at the "above quota" price (Carter et al. 1996).

c. Loosening of Government Control and Price Rise

From 1978 onwards, production exceeding the production quota and production from family plots were released for sale on local free markets and private long-distance trading also became permissible. However, the government continued to buy excess grain at a "negotiated price".

The reintroduction of family farming meant that sown area plans could no longer be enforced directly. Procurement quotas and price policy, therefore, now became the principal means for market intervention. While quota prices for grain had been raised by a mere 17 percent between the mid-1960s and 1978, they doubled by 1984. Although grain prices were still below world market level, this new incentive coupled with the freedom resulting from the newly introduced Household Responsibility System encouraged farmers to accelerate grain production. This led to a massive grain surplus in 1984. Producer prices had been raised while urban food prices remained at the same low level. Thus, the state owned grain marketing system was forced to become a major subsidizer of urban grain supplies. This absorbed a quarter of the government budget in the early 1980s (Carter et al. 1996).

d. Contract Purchasing and End of Administrative Industry Supply

The storage problems which arose in 1984 prompted the government decision to convert the procurement system into a so-called "contract purchasing system" whereby farmers could sign a contract with the government on a voluntary basis. The former "basic quota" and "above quota" prices were replaced by a fixed "contract price" which was, however, 35 percent lower than the average price previously paid for the two quotas. In addition, from this time on, grain processing enterprises had to pay the government the "negotiated price" or buy their grain directly on the free market (Carter et al. 1996). In 1986, these state contracts became compulsory and prices were raised after farmers had failed to fulfill their contract obligation in 1985 in response to the lower prices.

During the rural economic boom from 1985 on, there were fewer incentives for farmers to grow grain. An increasing number of farming households were unwilling to sell grain under the procurement contract system, in spite of the fact that they could benefit from certain government input subsidies in exchange. With a view to solving this problem, the government decided to enhance the amount of grain procured under the contract system from 75 million tons in 1985 to 89 million tons in 1989 (Carter et al. 1996).

e. Attempts to Relax Grain Market Control 1990-93

Up until 1991, retail prices for grain and oil had remained almost unchanged in China for about 25 years. The continuation of quota obligations at producer prices below market level was based, in the main, on the fear that any increase in urban grain prices would trigger a rise in urban wages, in particular those paid by state industries. Following the reduction of contract quotas in the late 1980s, procurement grain could no longer meet urban demands. As a result of this, the government was obliged to buy grain at the higher market prices to cover its annual requirements. Since retail price levels were still low, the government was now directly subsidizing these low prices (Tuan and Cheng 1999).

However, by 1990, urban wages had increased as a result of developments in the non-government controlled sector of the economy and management system reforms in state-owned enterprises (Carter et al. 1996). The government now finally dared to raise urban retail prices for the first time in almost 25 years (Ke 1995). Prices for rationed grain were raised by 20 percent in 1991 and a further 40 percent in 1992 thus almost eliminating the gap to market prices (Lin 1994). As soon as rationed grain prices neared free market prices, urban consumers shifted part of their purchases to free markets as the quality of the products offered there was higher. The grain rationing system was abolished as the monthly grain ration was no longer needed (Carter et al. 1996).

In early 1993, the central government announced its intention to reduce its involvement in agricultural marketing. Provincial governments became responsible for inter-provincial shipping. Fixed prices for contracted purchasing were to be replaced by prices at market level (Cater et al. 1996.).

In 1993, the Chinese economy suffered double digit inflation. Prices for manufactured agricultural inputs increased by 14.1 percent[3] and in rural areas, the price of fuel and building materials increased by as much as 32.2 percent and 28.2 percent respectively (SSB RSY 1994). These major increases in production costs contributed to a 13.2 percent rise in food prices. The government had not specified which market price, i.e. which month's price, would be valid, and therefore farmers were reluctant to sell their produce since they expected grain prices to climb even higher. At the same time, farmers in the Southeast coastal areas, a region with a traditional grain deficit, were released from the pressure to fulfill their contract quotas. Consequently, some farmers shifted their resources away from grain to more profitable production activities. This led to a decline in grain output in these areas (Carter et al. 1996). As a result, despite a record grain crop in 1993, rice prices started to rise in the South. This trend spread rapidly throughout the country and caused prices for all other grains to increase as well (Lin 1994b).

f. Panic Reaction and Deterioration - 1993/94

At the end of the year, the dramatic rise in prices caused the central government to bring back direct controls over the recently liberalized grain markets. Grain rationing and coupons, which had been abolished in 1992/93, reappeared in some areas and central government attempted to increase the quantity of mandatory quotas from 50 million tons to 90 million tons. Private traders were prohibited from participating in grain transactions before the government had fulfilled its own procurement targets (Lin 1994b). Local governments in surplus regions were unwilling to procure high quotas at these higher prices. Consequently, they

[3] Compared to an annual increase of 3-5 % in 1990-92.

blocked inter-provincial grain shipments with a view to forcing farmers to sell their contract quota at a lower price (Carter et al. 1996).

Although the announced increase in mandatory quotas was not enforced, those measures which were implemented raised farmers' expectations. The country found itself in an inflationary situation with spiraling grain prices. As a result, farmers continued to hold onto their produce (Johnson 1999). The trade blockade caused market shortages in deficit regions and resulted in a significant jump in grain retail prices in the Southeast coastal areas. Once again, this trend spread throughout the whole country.[4]

The fear of social unrest in urban areas caused central government to act in December 1993. A price ceiling was fixed for grain retail prices and 2.5 mmt of grain was released from the national reserves (Carter et al. 1996).

At the beginning of 1994, central government announced its intention to reestablish controls of grain purchases, fixed procurement prices and to force farmers to sow planned acreages. This policy reversal was viewed as a negative sign by farmers in surplus areas and discouraged them from increasing their production that year. This led to a 2.8 percent decline in production that year. The demand for grain was on an upward trend in 1994 due to ongoing population growth and rises in non-agricultural incomes (People's Daily 12/29/1994). In urban areas, the increasing stream of migrant workers created additional demand. In addition, the inflation rate was even higher than in 1993, causing consumer retail prices to climb another 21 percent (Carter et al. 1996). In November 1994, rural food prices surpassed the 1993 level by 41 percent (Chinese Business Times, 12/29/1994). In response, cities decided to restore the grain rationing system for the urban poor (Carter et al. 1996).

It would be forgivable to assume that all this market turbulence was merely the result of bad timing – i.e. the liberalization of the grain market at a time of high inflation. However, it is clear that policy-makers committed numerous errors that served to amplify these developments. First of all, government officials were worried about the rising grain prices. However, they were not as high as it seemed in 1993: in 1992, real grain prices had reached the lowest level since 1980 which represented a decline of over 35 percent from the peak price of 1989. In mid-1994, real terms grain prices were less than 10 percent higher than in 1983. What is more, increases in urban incomes had, to a large degree, already off-set the cost share of grain in total living expenditure making it highly unlikely that social unrest would have occurred. [5]

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[4] E.g. in the coastal provinces food prices went up by 30 percent in one month in November 1993 (Lin 1993).

[5] In 1994, the 5 percent of urban households in the lowest income bracket devoted a mere 12 percent of their total living expenditure to the purchase of grain. The average share of income spent on grain only rose by 1 percent as a result of the 1993-1994 price increases (SSB SYC 1995).

The immediate reaction of the government combined with ongoing market intervention encouraged farmers to believe that prices would continue to rise. In response, they increased their on-farm grain stocks considerably in 1993 and 1994.[6]

In spite of the fact that the government had announced its intention to release a certain amount of grain from national stocks, there is evidence that national grain reserves actually increased during 1994, which led to a further reduction in grain supplies. Finally, foreign trade decisions were not flexible enough to alleviate the situation. In fact, the opposite was the case: in spite of rising domestic grain prices in 1993 and 1994, China continued to export grain during these two years. This aggravated the situation in domestic grain markets even further (Johnson 1999).[7]

g. The Governor's Responsibility System

The Governor's Responsibility System, also called the "grain bag", was introduced in 1995 for food security reasons. Under this system, the provincial leadership is called upon to assume the ultimate responsibility for securing the grain needed in the provinces (MOA 1995). The policy defines the provincial leaders' responsibility for maintaining an overall balance between the supply and demand for grain within their province. At the same, time they are obliged to stabilize the grain production area, output and stocks and to utilize local reserves to regulate grain markets and stabilize grain prices. This policy has achieved some positive results since it was instituted. However, it impedes the efficient allocation of resources and promotes a return to regional protectionism (Tang 1995). Every province now strives for market stability within its own area, in many cases at the expense of other provinces. In times of market shortages, certain major grain producing provinces often prohibit inter-provincial grain shipments, thus aggravating market balance problems on a nation-wide scale (Tuan and Cheng 1999).

The components of the mandatory procurement quotas for different products now vary from one province to another, giving due consideration to the social-economic and natural environment of the respective regions: rice and wheat are subject to procurement throughout the country, corn and soybeans in the North-east provinces. Grain crops, such as potatoes, peas and sorghum are not con-

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6 Between the end of 1992 and 1994, on-farm grain stocks rose by an estimated 75 mil. tons. This is a considerable amount since annual non-farm use of grain was in the order of 80 mil. tons with about 50 mil. tons for direct urban consumption.

7 Chinese grain trade has not changed significantly from the days when the entire economy was governed by central planning. At least, this was the case through 1996. Basic decisions on amounts and composition of the grain trade – imports and exports - are taken well in advance of the beginning of the calendar year in which trading is to take place. There seems to be no procedure for modifying thee decisions.

trolled as stringently and their production and consumption respond to market forces. Other minor grains such as millet, beans and oats are controlled in those provinces where the production of these crops is relatively important. The sale of production exceeding the procurement quotas on free markets was readmitted from 1996 (Carter et al. 1996).

h. Price and State Marketing Support

In spite of continued government intervention, fixed state quota procurement prices doubled between 1993 and 1996. Nevertheless, even though quota procurement prices for grains increased by 40 percent in early 1996, they were still below market level. This price relationship was reversed in 1997, largely as a result of two consecutive years with record, bumper harvests (Tuan and Cheng 1999), massive grain imports[8] and the reduction of on-farm grain stocks in 1995 and 1996.[9] In 1997, market prices began to fall below quota prices. Corn, first of all, was affected in spring, followed by wheat and rice in summer (Johnson 1999).

In order to protect the interests of grain producers and to meet food security goals, central government launched a price support policy and fixed a support price level for all grains nation-wide (Ke 1998). Under the terms of this policy, farmers received a higher protection price for quota grain and a somewhat lower reserve price for any further quantity they wished to sell (Johnson 1999). In addition, central and provincial governments were obliged to provide a 0.12 Yuan subsidy for the marketing of each kilogram of grain purchased by state grain marketing enterprises (Ke 1998).

This support program was not, by its very nature, a real price support policy, as it was the marketing enterprises, and not the government, that had to buy the grain from the farmers and carry the market risks. However, the marketing system received massive support involving as much as 19.7 billion Yuan in 1996/95, 40 billion Yuan in 1996/97 and 120 billion Yuan by the end of 1997. These losses exceeded the total 1997 expenditure by urban consumers for the purchase of grain (Johnson 1999).

i. Grain Distribution Reform 1998

In May 1998, a new grain distribution reform was announced. The basic concept behind this reform involved a transitional period followed by the total liberalization of the grain sector. This idea was, however, rejected due to the huge debt accumulated by the state grain system. Instead, a different policy was introduced

8 Again these imports, however, were again the opposite the Chinese market had needed these years.

9 Once again, these imports were contrary to the needs of the Chinese market in these two years.

which aimed at recovering the huge government debts and raising market prices over government procurement prices. This involved tightening up the country's grain marketing system and restoring government monopoly over grain procurement.

After the new policy was introduced, only state grain enterprises were allowed to buy grain from farmers. Other grain dealers were only permitted to retail grain they had purchased from government grain marketing enterprises. This change was designed to permit government grain enterprises to monopolize the country's grain marketing system, thus ensuring that grain prices rose above the government protection price. In this way, the government could discharge its debts and grain marketing could return to its former mode of operation (Tuan and Cheng 1999).

Many economists, both Western and Chinese, doubted this policy would succeed. In fact, the debts of the state-owned grain enterprises continued to grow and it was estimated that they would rise another 9 to 10 billion Yuan by the end of 1998. Consequently, certain policy adjustments were implemented in 1999. Although the current program may well help to reduce the huge surplus in grain production and reduce excess grain stocks, the source of the problem will only be eliminated when China's grain marketing system is liberalized (Tuan and Cheng 1999).[10]

2.2.3 Cotton Market Policy

The Chinese government traditionally regarded cotton as a strategic crop. Within the scope of government development strategy, domestic cotton production was called upon to supply the textile industries at low cost in order to accelerate industrialization. This meant that the government tried to keep cotton prices as low as possible by forcing production and compulsory procurement as well as maintaining full government control of marketing (Carter et al. 1996).

a. Tight Control

Cotton production, like grain, was subject to a "Unified Procurement" system whereby the government was the sole buyer. While private marketing channels existed for other crops, the government remained the sole purchaser of cotton, even after 1978. The cotton surpluses which came about in the early 1980s led to a reduction of the quantity purchased by central government in 1985. However, farmers could not sell their surplus as the state maintained its monopoly on cotton. In response to this, the area under cotton was reduced dramatically leading to a grave supply shortfall for the textile industry the following year.

[10] Obviously the state marketing system is still employing 4.1 million people whose salaries alone are already producing considerable costs (Johnson 1999)

While marketing control was eased for most crops during the second half of the 1980s, the controls governing cotton marketing became even more restrictive in that procurement was rigorously enforced. Private marketing was still not allowed.

Since the textile industry could only provide significant profit and tax revenue as long as cotton prices were low, there were frequent reports of political conflicts between farmers and government, as well as between different levels of government. Central government tried to enforce planned distribution, local governments in cotton producing areas wanted to retain as much of the crop as possible for their local mills, and manufacturers in other areas offered farmers higher prices.

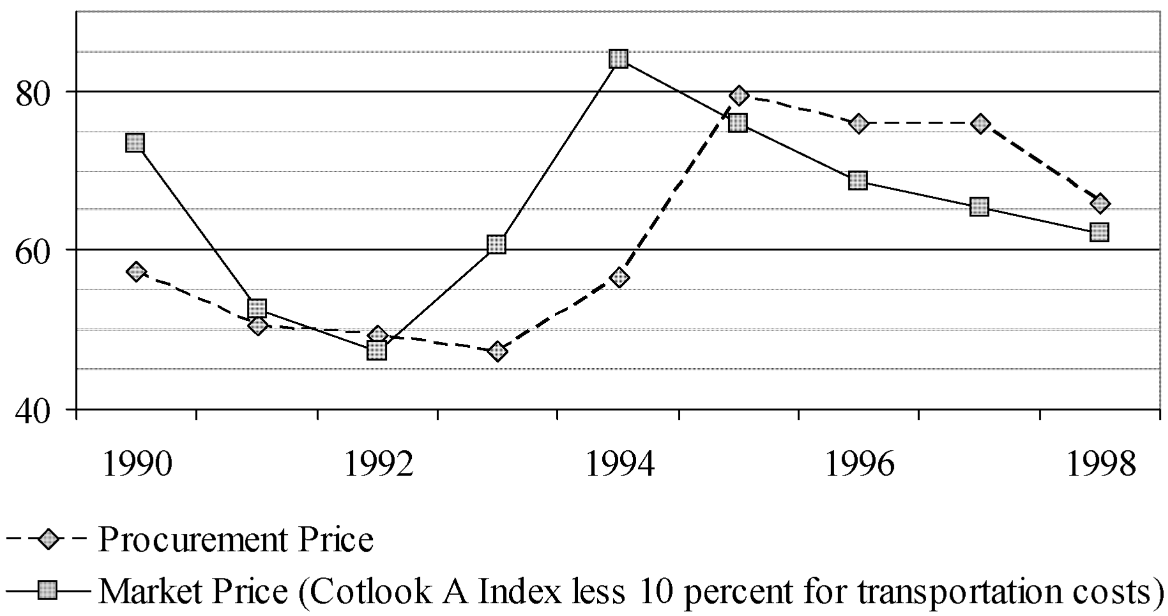
In the late 1980s, this so-called cotton purchasing war became increasingly serious as the gap between the procurement price and the world market price widened. While government agencies competed with each other, farmers reduced their production in response to the low price, held back on deliveries or tried to sell directly to manufacturers, finally leading to serious cotton shortages in 1994. Cotton production sank to one third of its former level. There was a shortage of cotton for the textile industry and textile plants were unable to continue operating (Carter et al. 1996).

b. Dramatic Stockpiling

The central government prohibition of all forms of marketing activities, except those engaged in by official cotton agencies, meant that direct purchasing between farmers and textile mills and inter-provincial trading by private firms and provincial governments was strictly forbidden (USDA 9/97). Import regulations were relaxed to make up the supply shortfall, domestic mills were allowed to import cotton to manufacture textiles destined for export and certain import taxes were abolished (USDA 6/98). The purchase price was raised to encourage farmers to increase their cotton production.

Figure 2-1 shows that although the government made efforts to bring the administered market price into line with the world market price, it always lagged behind the actual market situation due to the inflexibility of the system.

Up until 1994, the price for home-grown cotton in China had been lower than the world market level. This made Chinese cotton extremely attractive for the domestic textile industry. However, in 1995 the Chinese cotton price surpassed the world market price and remained above it during the following years. The government purchased cotton from farmers at the official prices and, in addition, encouraged them to expand cotton production. The textile industries found ways of continuing to use cheaper, imported cotton by establishing bogus joint-ventures; a black market for cotton developed (USDA 6/98). Finally, the situation arose whereby China continued to import cotton, in spite of the fact that home-grown production exceeded domestic demand. During this period, China was the world's largest importer while domestic surplus was being stockpiled.



[1] US cents per pound

Figure 2-1: Cotton Prices[1] in China and World Market

Source: Shaw 1998

c. Step by Step Adjustment Towards Liberalization

According to reports, stocks approached four million tons in late 1997. Storage and management costs were becoming unacceptable (Shaw 1998). In response, the Chinese government launched a reform package, the immediate purpose of which was to increase demand for domestic cotton, while reducing imports (USDA 6/99). During late 1997, a large number of illicit import establishments were discovered and shut-down. In January 1998, new quotas and import procedures were introduced and former tax exemptions were reduced. However, the joint-venture mills, which accounted for 50 percent of imports, were exempt from these measures. Chinese cotton prices were lowered in mid-1997, in 1998 and again in 1999 (USDA 10/97, 1/98, 7/98,). However, this led to opposition from farmers and cotton distributors since state distributors were now stuck with the huge stockpiles they had bought at higher prices (CAN 9. 1998).

The price reduction and tightening of imports did not help to reduce these stockpiles. In 1998, therefore, China started to export directly from its stocks. This continued in 1999 and, coupled with the reduction in imports, these exports exerted much pressure on the world cotton market (USDA 6/98, China Daily 14.4.1999).

Finally, in December 1998, the State Council approved a package of reforms designed to make the cotton sector fully market-orientated as per September 1999 (China Daily 25.12.1998). These measures foresaw a floating price system which would replace the tradition of cotton purchase prices fixed by the government. The only government intervention would take the form of a reference price issued before the purchasing season (China Daily 25.12.1998).

2.3 Foreign Trade

2.3.1 Overview

a. Aims

Up until the mid-1980s, the export of agricultural products played a crucial role in Chinese foreign exchange earnings. Products that had been procured at a low price could be sold on the world market at a considerable profit.

In the early 1980s, the government decided to import more wheat and cotton and thus encourage farmers to specialize in farm products suited to local, natural conditions. The development of the textile industry was designed to provide off-farm opportunities for surplus rural labor (Tuan and Cheng 1999). In recent years, the agricultural export share has declined drastically and is no longer of major importance[11] (Tuan and Cheng 1999).

Over the last 4 to 5 decades, food security and self-sufficiency - i.e. grain - have been a dominant theme of China's trade policy. The government has always tried to keep food imports low while pushing domestic production at the same time. As a result of the animated debate on China's future ability to feed its population, the self-sufficiency goal for grain was defined quantitatively at 95 percent in 1996. This translates into net imports of 25 million tons of grain at present and 32 million tons by 2030, given that total domestic consumption is estimated to reach 640 million tons (Tuan and Cheng 1999).

b. Import Activities

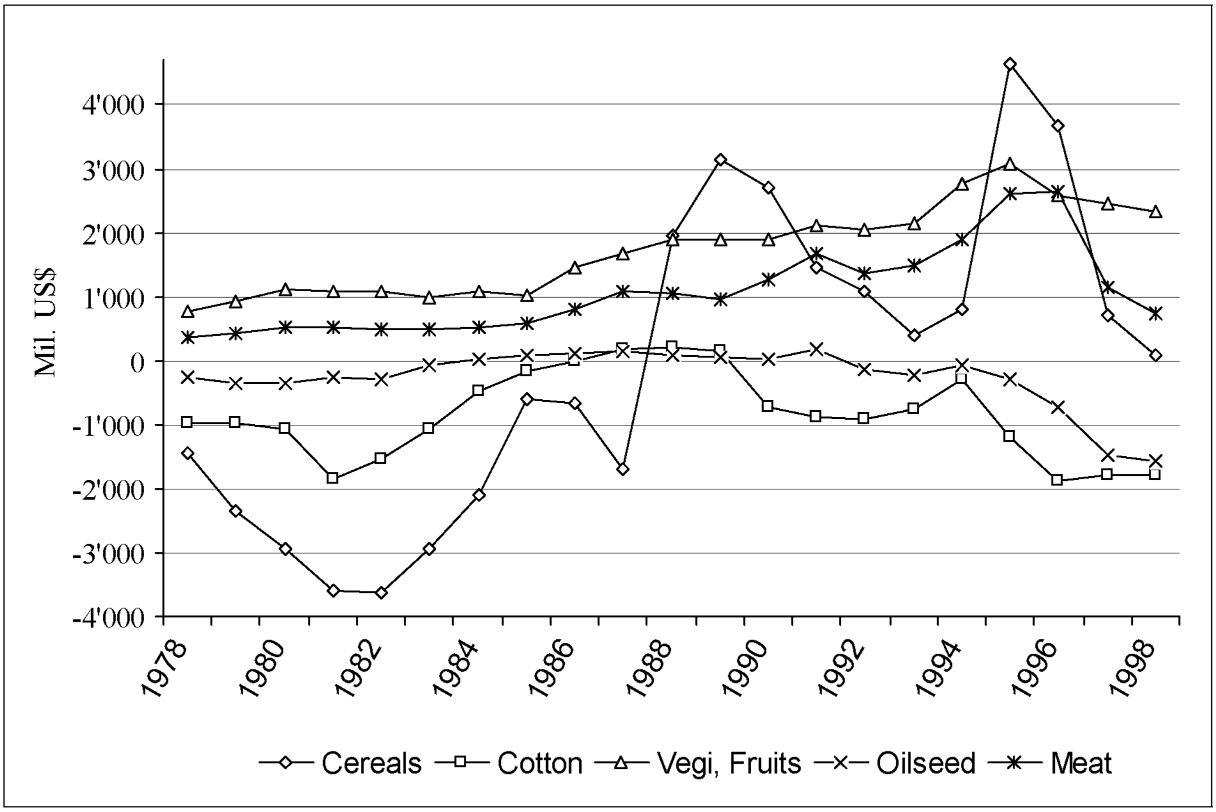
After 1978, China re-emerged as a significant trading nation with an increase from 0.8 to 2.5 percent of total world market volume and became the world's 10th largest exporter in 1994. Commodity composition of trade came closer to the comparative advantages of Chinese agriculte than in pre-reform eras. This meant that there was a shift from raw materials to labor intensive manufactured goods. The share of primary commodities in total exported products sank from one third in 1978 to one seventh in 1993 (Lardi 1994).

For classification see footnote 3 page 11

Figure 2-2 shows that there was a steady increase in net exports of labor intensive agricultural products such as vegetables, fruit and meat up until the mid-1990s. China still remained a net exporter of labor extensive products such as

[11] see Figure 2-3 page 49

cotton and oilseed. Since the grain trade is largely government controlled, foreign trade activities are also politically motivated.



For classification see footnote 3 page 11

Figure 2-2: Net Exports of Major Agricultural Products 1978-1998

Source: FAO Database, 2000

c. The Grain Trade

At one time, China had been a grain exporter but in the 1950s, following the introduction of the People's Communes, it became an importer with average imports of 3.45 million tons (mmt) of grain per annum between 1961 and 1978 (Carter et al. 1996). With the 1978 reform program, a general increase in imports was sanctioned to compensate for the decline in production brought about by the reduction of the farmers' procurement burden and by improved incentives in other agricultural activities. Rapid growth of grain yields in the early 1980s reversed this trend and by 1985 China had become a net exporter. Imports became necessary once again due to continued strong demand growth and successive poor harvests from 1985 to 1988 (Huang J. et al. 1996). In 1989, overall grain imports were again reduced almost to self-sufficiency level (Huang J. et al. 1996). These imports then declined thanks to reduced on-farm-wastage and production increases. Increases in corn production boomed in the Northeast of China and led to such high corn exports that, in 1991, they could off-set imports for the first time. China then remained a net exporter of grain until the export ban in 1995 (Carter et al. 1996). In 1995 and 1996 imports rose sharply again (Huang J. et al. 1996).

Grain trade planners made frequent attempts to arbitrage the price difference between rice and wheat (Huang J. et al. 1996). As a result, 90 percent of grain imports since 1961 have involved wheat from the USA, Australia, Argentina and recently the European Union (Carter et al. 1996). During the 1980s and early 1990s, average imports amounted to 12.5 mmt/year (Huang J. et al. 1996). Over the last decade, China both exported and imported rice, and became a net exporter. While Indica varieties were imported in order to meet the consumer demand of the Southern Chinese population, Japonica varieties were produced in the Northern regions for export to Japan (Carter et al. 1996). Up until 1994, China also exported soybean in the order of 1 mmt per annum. In the early 1990s, substantial quantities of corn were exported from the Northeast provinces to Northeast Asian countries leading to shortages elsewhere in the country. Transportation bottlenecks along the northeast corridor kept large quantities of maize and soybean from arriving on the domestic market in the South (Huang J. et al. 1996).

2.3.2 Policy Measures

In 1999, China implemented three measures to control foreign trade: tariffs, licensing and quotas.

Each year, China's Customs Administration establishes a set of duties for each commodity that is to be imported or exported. The tariffs fixed by the Chinese Customs Administration are often used for both developing and controlling the overall conditions governing the country's economy. Two current types of tariffs are applicable to agricultural commodities, namely preferential tariff rates for countries that have a bilateral preferential trade agreement with China and general tariff rates for other countries.

In general, the Ministry of Foreign Trade and Economic Cooperation (MOFTEC) is responsible for issuing import and export licenses, although licensing is also delegated to provincial authorities. Import licenses are issued for each category of goods, for one year, with no extension and no quota specifications for any countries or regions. The MOFTEC issues these licenses for merchandise based on the availability of foreign exchange as well as on domestic supply and demand conditions. Export licenses are issued according to bilateral or multi-lateral trade agreements or to prevent excessive exports of certain products. In 1999, major agricultural products were subject to export licenses.

Import quotas allow the Chinese government to exercise efficient control over import items. They are imposed on products that inhibit domestic production or represent a waste of foreign exchange. Import quotas are issued by the State Planning and Development Commission and in some cases by provincial planning commissions. In 1999, the import of grains, edible oils, wool, natural rubber, sugar, chemical fertilizers, tobacco and related products was subject to import quotas (Tuan and Cheng 1999). Other non-tariff measures include a registration system for special imported merchandise and phytosanitary inspections (Tuan and Cheng 1999).

Table 2-1: Import Tariffs for Selected Agricultural Products in 1998 (percent)

Item	Above Import Quota: Preferential	Above Import Quota: General	**Within Quota**
Rice	99.2	180	0-9
Wheat	114	180	1-35
Corn	77	180	0-35
Barley	91.2	160	0-40
Oilseeds	41.3	93.5	0-40
Vegetable Oils	49	86.8	9.7-20
Cotton	3	8	
Sugar	30	53.3	

Source: Chinese Customs Administration

In 1992, China's government cut tariff rates for imports on 2898 tariff lines as part of its bid to gain WTO membership and two more cuts were announced on 3371 and 4900 tariff lines in 1993 and 1994. The government once again lowered tariff rates on 4874 tariff lines by 26 percent in October 1997. This represented a drop in the country's overall average tariff from 23 percent to 17 percent, whereby it must be mentioned that China's overall average tariff rate was 43.2 percent in 1992.

China's overall average 1999 tariff rate for agricultural products was 21.2 percent with 16.5 percent on raw materials, 24.2. percent on semi-finished products and 27 percent on finished products. In general, the average tariff rate on live animals and animal products was about 20.6 percent and 6.9 percent for crop products, 22.7 percent for oils and fats and 28.7 percent for food, beverages, tobacco and wines. While other tariff lines were lowered, the rates for imported grains and cotton were not adjusted.

The government declared that direct export subsidies were to be abolished as per January 1991. However, since the government continues to play a major role in procuring, pricing and trading with major agricultural commodities, it can be argued that Chinese agricultural exports are still subsidized.

Value added tax refunds are granted on export commodities and also on certain imported goods whose import is considered desirable.

China's major grain imports and exports are still handled by the state trading agency, COFCO (China National Cereals and Oil and Foodstuff Import and Export Cooperation). The state trading system can be used to set up trade barriers and to discriminate against certain buyers or sellers. Hence, they contravene the most-favored-nation principle of WTO. The system limits the flexibility which is so vital in constantly changing domestic and international markets. Grain imports and exports are handled by specialized state agencies which are not involved in domestic grain marketing. The state trading entities receive grain from domestic state marketing agencies for export and, in turn, supply the domestic marketing agencies with imported grain for sale on the home market. In some cases, a substantial share of the grain supplied to the state trading companies is "quota grain" purchased from farmers at low quota prices. Reckoning with these lower quota prices, state trading companies exported grain even when domestic prices were well above world prices, e.g. for corn in 1994. This discrepancy between domestic and foreign trade policies has caused instability in the trading with certain major agricultural commodities. In some cases, trade changes have even tended to aggravate rather than alleviate domestic price fluctuations (Tuan and Cheng 1999).

2.3.3 Level of Protection

China has several agricultural non-product specific policy measures that would find a place in the "green box" under the WTO agreement. These include: research related programs, support for agricultural organizations and wages for technicians and management staff, expenditure on basic and agricultural infrastructure such as dams, irrigation systems, roads etc., agricultural development funds, policy subsidies for the marketing of grain for the grain rationing system serving the armed forces, urban residents and people living below the poverty line, low-interest loans for grain security purposes, subsidies on food grain rations in big cities, natural disasters assistance, rural elderly and poverty assistance and low-interest loans granted to poverty areas.

Table 2-2: AMS, NPR, and PSE for Major Agricultural Products 1986-1997

	AMS 1993-95	NRP 1986-90	NRP 1991-97	PSE 1991-97
Rice (x)	-23.8	-3.0	-10.7	-39.1
Corn (x)	-	31.6	-16.7	-23.1
Soybeans	-20.5	92.5	124.1	21.0
Wheat	-8.9	49.0	45.3	-3.7
Sugar	-3.7	134.7	128.1	60.6
Cotton	-1.1	-12.7	-14.0	-22.5
Ed. veg. oil	-	100.0	105.3	50.8

AMS = Aggregate Product Specific Support; NRP = Nominal Rate of Protection, percentage difference between the domestic and border price; PSE = Producer Subsidy Equivalent, subsidy equivalent needed to compensate producers for termination of all government support and protection measures; (x) = Export-orientated crops

Source: Cheng 1999

Although Chinese farmers do receive some subsidies on inputs, aggregate support (AMS)[12] for agricultural commodities in the years 1993-95 shows that all were negative. This indicates that Chinese farmers were, all in all, taxed rather than subsidized (Table 2-2). Existing support for agricultural commodities, therefore, is not likely to be an issue in the matter of China's accession to the WTO.

The level of government protection (PSE)[13] for the production of major agricultural products has changed and fluctuated over the last two decades. Levels of support increased in the mid- and late 1980s and early 1990s. These changes were consistent with government reform of the procurement system, the structural changes which took place in the 1980s and the implementation of the price adjustment and price protection policy in the early 1990s. Calculated Nominal Rate of Protection (NRP)[14] shows that the protection level has been higher for import-orientated products than for export-orientated products. It also implies

[12] Including market support subsidies, non-exemption direct payments and other specified agricultural commodity support. China's commodity quota prices also fall within this category.

[13] PSE = Producer Subsidy Equivalent, subsidy equivalent needed to compensate producers for termination of all government support.

[14] NRP of agricultural products can be expressed as a percentage difference between the domestic and border price.

that China's reform policies tended to encourage the production of more import substitutes (Tuan and Cheng 1999).

2.3.4 WTO Accession

a. Overview

China joined GATT in 1948 but pulled out following the Communist takeover in 1950. 1979 saw the advent of Deng Xiaoping's "reform and opening policies" and in 1986, the country once again applied for GATT membership. Trade negotiations suffered a serious setback following the Tiananmen Square massacre in 1989 but China launched a new effort to join GATT in 1994. In the 1990s, a series of liberalization measures were adopted to accelerate market-orientated reforms and, to a certain extent, to support the application for GATT/WTO readmission (Wang Z. 1997). US President Clinton and Zhu Rongji signed a statement in April 1999 in which they committed themselves to complete negotiations by the end of 1999. An agreement was reached between the US and Chinese negotiators in November 1999 (Xiaopeng 1999) and approved by the US Congress in May 2000. By Summer 2000, most other countries have signed an agreement with China on the conditions for accession.

b. Positions

China's main motive for wishing to join the WTO is the prospect of better access to markets in the industrialized countries. In the 1990s, China was the country with the highest number of anti-dumping suits world-wide. In several cases, the Chinese were even refused market access. A WTO deal would help avoid this kind of discrimination, or allow China to go to arbitration to settle trade disputes (SCMP 16,29.9.99).

In 1993, and again in 1996, China reduced tariffs to an average level of 23.2 per cent and abolished several import controls. Currently, most developing countries maintain a simple average tariff of 15 percent. The Chinese tariff level, therefore, is still too high to qualify for WTO membership (Wang Z. 1997). An amendment of the Chinese patent rights law is expected (SCMP 29.9.99), the purpose being to improve the protection of intellectual property rights.

China would like the "gently does it" advantage of developing-nation status. This would allow it to open its markets more slowly, while still benefiting from enhanced access to industrialized countries' markets and maintaining its tariffs at a higher level (SCMP 29.9.99) The party leadership is particularly concerned about its highly subsidized State Owned Enterprises.[15] China's economy is widely felt to be dangerously weak due to the slow progress of reforms, princi-

[15] 1998 state companies made profits of 49 bil. Yuan and received 150 bil. Yuan in the form of government subsidies.

pally in the banking and state enterprise sectors. In spite of the increasingly important role played by the private and collective sectors, state enterprises are still seen as a key component of the economy. However, they are heavily indebted to the state banks which have continued to fund the state sector, by order of the government, which fears a sharp rise in unemployment if state enterprises are allowed to fail. WTO membership will force the government to implement the necessary reforms as many companies will not be competitive in an international environment (SCMP 22.9.99).

In addition, WTO membership would help the reform forces in the Chinese government by giving them a reason to complete the reforms of the market system and the commercialization of the state owned enterprises. Improved transparency in Chinese markets might also reduce the opportunities for corruption (Reuters, Yahoo 27.9.99). A transparent market environment, too, combined with improved market access, might not only boost foreign investment (SCMP 16.9.99), but also enhance the flexibility of Chinese firms, allowing them to develop in productive sectors of the economy.

In addition, as an officially recognized participant in the world economy, China would be in a better position to protect its national interests. WTO membership would also permit China to exert influence on the outcome of future negotiation rounds (Reuters, Yahoo 27.9.99).

Both the USA and the EU are demanding better access to Chinese markets for agricultural products, and manufactured goods and services, in exchange for opening their markets to the Chinese textiles industry. The US trade deficit has been growing over the past decade, reaching an all time high of 6.31 billion US$ in 1999 with declining US exports to China. Chinese accession to the WTO might enhance this trend. This is why the USA is insisting on the adequate opening of Chinese markets to foreign goods and services and, furthermore, an opening of its financial and banking sectors. The EU is demanding the right to establish branches for life insurances, majority ownership in telecommunications, a reduction of tariffs on cars and spirits and permission for European banks to trade in local currency and securities (Reuters, Yahoo 21/9/99).

c. The Agreement Between the USA and China on Agriculture

In October 1999, China and the USA signed an agreement on the conditions under which China would be permitted to join the WTO. China agreed to open up several key sectors, in particular telecommunications, as well as granting permission for the manufacture and sale of products to China without government middlemen (Doud 1999). These commitments move Chinese agricultural foreign trade policy towards a system based almost entirely on (lower) tariffs, the abolition of quantitative restrictions on imports, scientifically-based sanitary and phytosanitary standards, a reduction of the role of state trading enterprises for key commodities and the elimination of export subsidies (Barshefsky 1999).

China will reduce the overall average tariff for agricultural products to 17 percent. All tariff cuts will be implemented by 2004, the date by which the other WTO members will also have implemented their Uruguay Round tariff cuts. All tariffs will be fixed, i.e. they cannot be increased anymore (Barshefsky 1999).

Table 2-3: Tariff Rates According to the WTO Agreement Between the USA and China

		1999	2004
Meat:	Beef	45%	12%
	Pork	20%	12%
	Poultry	20%	10%
Fruits:	Citrus	40%	12%
	Grapes	40%	13%
	Apples	30%	10%
	Almonds	30%	10%
	Soybeans		3%
	Wine	65%	20%
	Cheese	50%	12%

Source: Barshefsky 1999

China will also eliminate any import quotas and replace them with Tariff-Rate Quotas (TRQs) with average tariff rates of 1-3 percent within the quota. These TRQs are substantially above present import levels, but allow space for future growth. An initial share of the quotas will be allocated to private traders to ensure that the quotas are fully exploited. Any quota reserved for a state trader which is not utilized will therefore automatically be made available to any entity entitled to trade.

In the case of soybean oil, the TRQ starts at 1.7 million. tons, will rise to 3.3 million. tons by 2005 and will be eliminated by 2006. Private sector trade will begin at 50 percent and rise to 90 percent (Barshefsky 1999). The total tariff rate quota for the three principal grains is only 21.8 million. tons by 2004. This does not represent a major rise as China imported 20 million tons in 1995 (Xiaopeng 1999) TRQ for wheat will amount to 7.3 million. tons on accession and rise to 9.3 million. tons. In the late 1990s, the import level was under 2 million tons. Initially, the private sector will receive 10 percent of this quota. The average import level for corn was 250'000 tons in the late 1990s. The TRQ will be 4.5 million on accession and rise to 7.2 million tons, whereby the private sector will receive 10 percent of the import quota in the initial phase. TRQ for rice will be 2.6 million tons on accession and rise to 5.3 million tons. The current import level is 250'000 tons. 50 percent of TRQs will go to the private sector. The import level for cotton in the late 1990s amounted to 200'000 tons. The TRQ will be 743'000 tons, rising to 894'000 tons. The private sector will hold 67 percent of the TRQs (Barshefsky 1999).

It is feared that the implementation of these measures might have a negative effect on Chinese farm prices (Driver 1999). However, this fear does not extend to all areas of agriculture. Tariff cuts for wine and cheese will not affect Chinese farmers much as these products are not major items in the Chinese diet. The cuts in the meat and fruit sectors are significant but these are precisely the domains where China's domestic producers are most competitive. In addition, Chinese prices of fruit were 40 to 70 percent below world prices in 1999, while pork was 60 percent and beef as much as 80 percent below world market prices. The WTO represents great export opportunities for Chinese producers of these items (Xiaopeng 1999) rather than heralding an import shock.

Chinese economists criticize the quotas for being too high and allowing major dumping of cheap imported grain. However, those officials who oppose this position argue that these quota volumes do not represent a significant change from existing trade patterns. Although tariffs have been cut to 14.5 percent, with domestic prices 20 to 70 percent above the 1999 world market level, the competitivness of Chinese grain could well be enhanced by WTO accession since prices are not boosted by production costs, but rather by the high marketing costs incurred by the inefficient state-owned system. In general, officials argue that the WTO will help China's agricultural sector to develop more quickly. It will provide an improved export environment, especially for fruit and vegetables and lead to an acceleration of technological change in the farming sector. Increased competition in the domestic market will result in improvements in the quality of agricultural products and promote efficiency in agricultural production processes. From a long-term point of view, this will lead to an increase in the size of farms and accelerate urbanization and industrialization (Xiaopeng 1999).

Provincial officials have a tremendous amount of autonomy in the application of supposedly national laws. It could take a year or even more, therefore, for provincial governments to organize subsidies so that China complies with this agreement. There is no guarantee that central government will make a concentrated effort to get the provinces to toe line, especially in regions where there is a risk that farmers, state trading enterprises and state factories might lose their markets to new competition (Driver 1999). By allowing the provincial levels to exercise a high degree of autonomy, central government can have it both ways, i.e. gain WTO market access without fully enforcing its most onerous concessions (Doud 1999).

Domestic critics are apprehensive that WTO membership will lead to a fall in farm incomes and consequently to problems of social stability. Poor farmers in inland China would be most vulnerable since there is a risk that imported products will be more competitive than products from this region.

Farmers in the coastal areas are less affected. Land scarcity and their proximity to consumer markets in the emerging economic centers has encouraged them to produce high value products which stand to gain export markets from WTO access. In addition, the coast already enjoys better integration with world markets because farmers have fewer barriers and middlemen to overcome in order to get their products onto the market. This situation is likely to improve even further. On the other hand, farmers in inland China depend heavily on the cash income they earn by selling their products in coastal areas. Major social problems could arise if this source of income is cut off as consumers switch to cheaper, high quality imports. The various regions of China already exhibit vast disparities in their development. A situation of this nature would amplify these inequalities and create great tension in inland China.

In the past, central government has tried to alleviate this problem by transferring incomes from the coast to the interior. However, the various loan and grants programs have been ineffective to a large extent because it was easier and more profitable to divert the funds to the booming coastal areas. Consequently, it will be equally difficult, from a political point of view, for central government to fully implement and enforce WTO requirements if it becomes evident that they create serious social problems. If effective efforts are not made to combat the underdevelopment afflicting rural inland areas, there is a very real risk that China will be unable to fulfill its marketing commitments (Xiaopeng 1999).

2.3.5 Analysis of and Projections for Chinese Agricultural Trade

a. Chinese Food Security in The Long Run

In 1995, Lester Brown published a book entitled "Who will Feed China: A Wake Up Call For a Small Planet" in which he advanced the following thesis: China's fast economic growth will lead to a rapid rise in demand for food, particularly products of animal origin, which, in turn, will lead to a massive increase in grain consumption. However, China has few possibilities for increasing its agricultural production due to its massive loss of cultivated area, in particular the area devoted to grain. Consequently, the country will soon become a massive importer of grain. These imports will by far exceed the world-wide export potential, due to declining yields throughout the world. As a result, world grain prices will rise so steeply that poor countries will not be able to afford to import their grain requirements (Brown 1995).

The book was hailed by the media and prompted scientists to respond with well-founded forecasts[16]:

[16] e.g. World Bank 1993, Huang J. et al. 1996, USDA 1996

Table 2-4: Projections for China's Grain Balance 2010 (mil. tons)

	Production 1995	Mitchell and Ingco 1993	Huang J. et al. 1997	USDA /ERS 1995	Brown 1995
Demand	375	502	513	443*	472*
Supply	355	483	486	403*	317*
Import	20	22	27	39*	155*

*linear adjusted

Source: SSB SYC 1995, Mitchell and Ingco 1993, Huang J. et al. 1997, USDA/ERS 1996, Brown 1995 cited in Fan and Agcaoili-Sombilla 1997

In line with Brown's own forecast, the studies anticipate an increase in grain demand from 375 millions tons in 1995 to 500 million tons in 2010, assuming the continuation of high-level economic growth. However, on the supply side it soon becomes clear that Brown's report is based on pessimistic and false assumptions with regard to an estimated decline in grain production of 100 million tons:

- Brown foresaw a 50 percent reduction in the total cultivated area due to construction and economic development. This cannot be found in any other study. The Chinese government identified the problem in the early 1990s and implemented appropriate laws to counteract it.
- Brown also underestimated the potential yield increase of Chinese agriculture, which is higher than previous studies suggested: official statistics underestimated the Chinese cultivated area by 30 per cent. Furthermore, technological innovation and the improvement of irrigation infrastructure is expected to permit further yield increases.
- In addition, the Chinese government has not been inactive. Over the last decade, the main objective of Chinese agricultural policy has been to ensure grain self-sufficiency. Recently, public investment in agricultural research and irrigation has been accelerated. Finally, Chinese port capacities and transport infrastructure are inadequate to handle the import of such immense quantities of grain.

Nevertheless, all the studies show that China might become an importer of 20-40 million tons of grain by 2010.

In line with several studies designed to discover the main source of agricultural growth in recent years, Kersten (1998)[17] found that China can maintain a high level of self-sufficiency in grain production if it invests consistently in agricultural technology to increase productivity. Without technological progress, China would become a long-term grain importer, assuming that economic and income growth remained high.

b. Changing Comparative Advantages in Chinese Agriculture

When comparing the 1992 data for Chinese resource endowment with the data for the rest of the world, it can be stated that China numbered among the countries with the lowest per capita area of arable land (except for Japan), the lowest average wage rate and the lowest capital intensity per worker. The ratio of skilled to non skilled labor was slightly higher than that of other Asian countries but much lower than that of industrialized countries. In line with the relative resource endowment, China was a net importer of capital intensive manufactured products and a net exporter of labor intensive manufactured goods and other primary products. The largest share was held by textiles and other light manufactured goods while minerals, processed food, forestry and fishery products also contributed significantly to the trade surplus (Wang Z. 1997).

The rapid economic reforms of the 1980s were accompanied by an equally rapid decline in agriculture's share of China's GDP and exports and its comparative advantage shrank accordingly (Anderson 1990).

In 1992, China imported wheat while exporting rice and other grain and non-grain crops, and was largely self-sufficient in livestock products. However, surplus in agricultural trade reflects China's food self-sufficiency rather than its comparative advantage (Wang Z. 1997).

Hayes and Fuller (1999)[18] applied the laws of comparative advantage to examine the impact of allowing free trade. By comparing Chinese agricultural production structures with those of the USA, they found that Chinese agriculture was far from its optimal input-output mix. They concluded that in an open trade environment Chinese agricultural production would focus on growing labor intensive cash crops, fruit and vegetables for export while land intensive crops such as wheat, feed-grain and rice would be imported. Pork and poultry production would also increase if capital inflow was allowed (Hayes and Fuller 1999).

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17 Kersten (1998) applied a multi-regional model to simulate the world grain market 1995-2005.

18 Hayes and Fuller (1999) applied a Heckscher-Onlin-Vanek (HOV) international trade model to examine what Chinese agriculture would look like if it had evolved free trade and full technological mobility. They applied the US input-output coefficient to find the revenue maximizing output and trade mix for China using existing Chinese resource endowment.

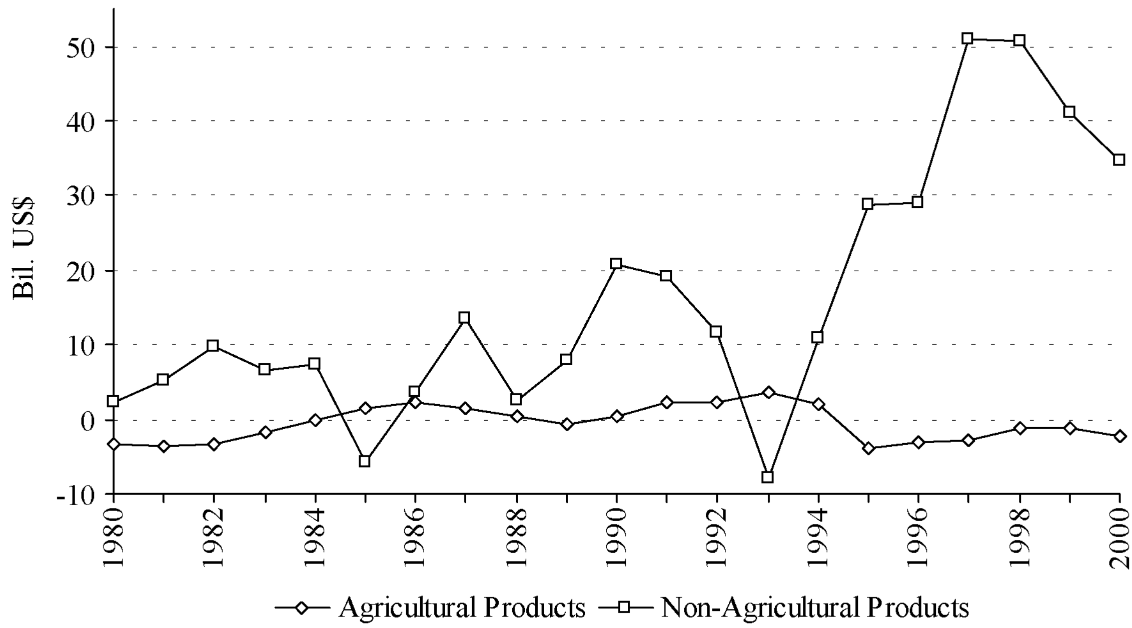


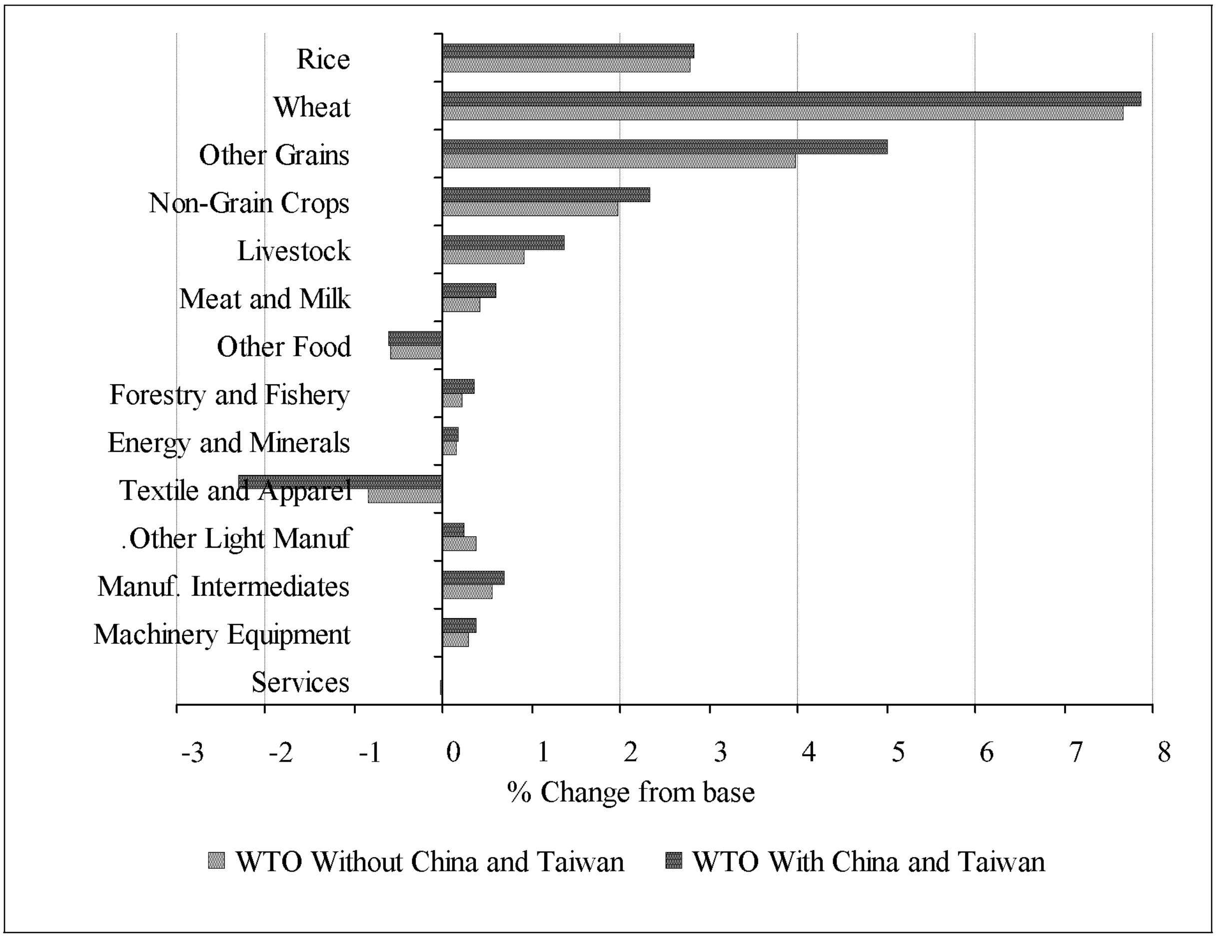
Figure 2-3: China's Net Exports, 1980-200

Source: SSB SYC 2000

c. Impact of China's WTO Accession

Anderson and Strutt (1999), and likewise Wang (1997), [19] estimated a GTAP model for China's WTO accession based on the 1992 data set and tried to pinpoint the effects of Chinese accession to the WTO. The impact generated by accession does not merely involve cuts in agricultural protection but also reductions in protection for the rest of the economy. China has offered to reduce its trade barriers by one third in tariff equivalents, whereby the cuts in agriculture are expected to be much lower than those in other sectors.

[19] Applying a computable general equilibrium model basing on the Social Accounting Matrix of the GTAP, effects of tariff changes on trade flows were simulated.



*GTAP Model based on 1992 data

Figure 2-4: Impact of Implementation of the WTO on World Market Prices for Agricultural Goods 2005: With and Without China*

Source: Wang Z. 1997

At the Uruguay Round, all WTO member countries agreed to implement measures designed to promote the opening of markets by 2005. These measures are expected to lead to significant increases in world market prices for most agricultural products. Grains will be affected most strongly, while prices for labor intensive industrial products, i.e. textiles will sink. Price changes accelerate when the same forecasts are calculated including China as a member of the WTO in 2005. While world market prices would rise for most food items, the price of industrial goods would deteriorate to the disadvantage of labor intensive products. These findings reveal quite clearly where China's strengths and weaknesses lie in international competition. Imports of agrarian goods and machines will rise while a drastic increase of textile exports can be expected. In response, countries in the Asian-Pacific region, the USA and Canada will increase their agricultural exports.

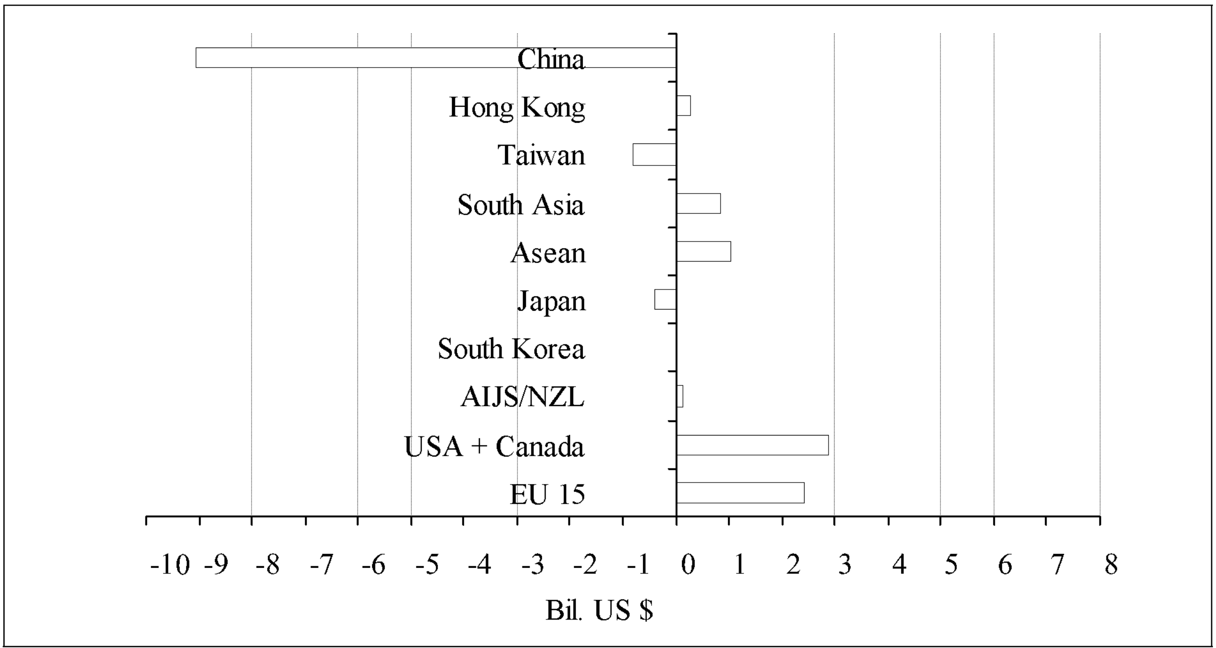


Figure 2-5: Impact of Chinese WTO Accession on World Agricultural Trade in 2005

Source: Wang Z. 1997

The effects described here are not a direct consequence of the reduction in Chinese tariff rates but rather of the induced economic growth in the Chinese textile sector. WTO membership will allow China to expand its textile exports and overcompensate the deterioration in terms of trade. This is expected to accelerate the growth of China's GDP [20] while global agricultural markets would be affected much more by an increase in Chinese trade volumes and prices. The improvement of China’s access to the textile markets in the EU and USA is therefore a critical factor, and it depends on the outcome of negotiations ("Multi-fibre Agreement") and the absence of any other factors likely to retard economic growth (Wang Z. 1997; Anderson and Strutt 1999).

The boom in Chinese labor intensive manufacturing industries would offset agriculture's production factors. In turn, this may lead to an increase in grain imports, especially feed-grain, and push world grain prices up again. These grains would be supplied by the USA, Canada and Australia. Increases in net rice imports would be supplied by the ASEAN and South Asian countries. China would become a cotton importer due to the rising demands of the domestic textile industry causing world prices for non-grain crops to rise. The labor intensive food processing industries would lose production sources to the textile and clothing industries thus reducing China's exports. World prices for processed food would decline slightly (Wang Z. 1997). The opposite would happen if China's growth

[20] The "Anderson and Strutt" model found 9.2 per cent instead of 7.8 per cent per year.

were to slow down, resulting in the Chinese agricultural sector becoming more competitive (Anderson and Strutt 1999).

Summary

Institutional Policy

After the founding of the People's Republic of China in 1949, farmland formerly owned by landlords and large-scale farmers was distributed among former small-holder tenants and the landless population. Starting in the early 1950s, more and more agricultural activities were carried out collectively, first voluntarily and later on a compulsory basis. In line with the collectivization of the rest of the rural economy, cooperatives were merged and finally comprised as many as 200 to 300 families. In 1958, the 740'000 cooperatives underwent yet another merger to form 25'000 communes each consisting of 4500 households on average. The objective was for these Communes to become the sole, overall rural institution and to assume responsibility for the management of all rural activities including agriculture, other economic activities and public services. Public resistance and mismanagement contributed to an appalling famine between 1959-61. In the following years, Communes were subdivided into Production Brigades the size of the former cooperatives and into Production Teams which corresponded to the former natural villages. The Production Teams were responsible for agricultural production, although they still found it difficult to fulfill production plans while running agricultural operations on a collective basis.

The Household Responsibility System (HRS) was introduced between 1978 and 1984 to enhance farmers' incentives to work. Under this system, communal land was allocated to farm households on the basis of household size. On average, each household received 0.56 ha. The farm households became tenants of their land and had to deliver a certain procurement quota at a predetermined price. Initially, the duration of these tenancy contracts was only 15 years and sometimes land was reallocated when family sizes changed. In the mid 1990s, however, contracts were extended to 30 years and reallocation was abandoned.

The introduction of the HRS led to the transformation of People's Communes into hierarchical administration levels: Townships (av. 4770 households), Administrative Villages (286 households) and Natural Villages (Cumin Xiaozu). Within this framework, the Natural Village was responsible for ensuring that the farmers fulfilled their procurement obligations.

When the Communes were dismantled, the townships and villages took over enterprises formerly owned by the Communes and Production Brigades. In an attempt to accelerate rural development, these enterprises also received new management freedom, special taxation (rates) and favorable bank loans. This finally led to a major boom of these rural enterprises in the late 1980s and early 1990s, mainly in the coastal provinces.

Although large state farms were never the major form of agricultural production in China, some do exist. In contrast to the People's Communes most of them were established on newly reclaimed land and organized more like Urban State Owned Enterprises. Some military farms were also set up to supply the Army. Unlike the People's Communes, both state farms and military farms still exist today.

Market Policy

Alongside the collectivization of the mid-1950s, the government established a complete state monopoly in agricultural trade. Almost all products were subject to a compulsory procurement quota program. The only goods admissible for sale at local, informal markets were fruit, vegetables and produce from private plots.

In 1978, the government officially permitted local marketing of produce in excess of the quota production, allowed private long-distance shipping and raised procurement prices substantially. While markets for fruit, vegetables and meat started to develop, more products were released for free market distribution. By the 1990s, most market controls and obligations had been abolished, with the exception of grain and cotton whose marketing remained under government control until recently.

Up until 1978, the Chinese grain market was completely under government control and all prices were fixed administratively by the government. After 1978, production in excess of the quota was released for private trading and a free grain market started to develop, parallel to the existing state distribution system. Although quota prices were raised considerably in the early 1980s, market prices were higher.

Following massive grain surpluses in 1984, the government considered converting the compulsory quotas into voluntary contracts. However, compulsory quotas were reintroduced after farmers began to shift their production away from grain. Even at that time, local officials found it difficult to enforce procurement quotas as free market prices were much more attractive.

Between 1991 and 1993, the Chinese government raised urban retail prices so that they reached the free market level in 1993. This resulted in the abolition of the state grain retail system. Finally, in late 1993, the government announced that market forces would be allowed to determine the grain price level in future. However, in 1994, the government was faced with the threat of steadily rising grain prices provoked by negative market signals to farmers, inappropriate stocks and foreign trade policy. This led to the reintroduction of sown area plans, administratively set prices, market control and the enforcement of procurement quotas.

Under the so-called Governor's Responsibility System, each provincial government was responsible for the grain balance in its own sphere of jurisdiction. To this end, procurement quotas and trade restrictions were applied to raise the provincial self-sufficiency level.

Market prices exceeded quota prices prior to 1996 only to fall below the quota price in 1997. It thus became an attractive proposition to sell grain to the state trading system. At the same time, central government instituted a grain price support program whereby a minimum support price level became compulsory throughout the country.

Around the mid-1990s, the Chinese state trading system was suffering alarming losses due mainly to its inefficient structure. This meant that the central and provincial governments were obliged to support the state grain companies with substantial subsidies, finally reaching 120 billion Yuan by the end of 1997. A state grain monopoly was reintroduced in 1998, i.e. private traders were forbidden to purchase grain from farmers. The purpose of this measure was to restore the profitability of state grain enterprises and help them recoup old debts. However, many economists doubt that this strategy will succeed as the structural shortcomings of the system are still present.

As in the case of grain marketing, the government strove consistently to keep cotton prices as low as possible. At the same time, production was forced by means of compulsory quotas and a state marketing monopoly. The textile industry yielded significant profits and tax revenue as long as cotton prices were controlled at a low level. For this reason, the regulations for cotton marketing became even stricter as from the mid-1980s. In response to these low prices and ever greater opportunities for black marketing, farmers' deliveries to the state marketing system sank continuously, finally leading to serious cotton shortages in 1994. As a result, import regulations were relaxed and domestic cotton prices raised.

However, Chinese cotton became less attractive in 1995, when its price overtook the world market price. The government still purchased cotton from farmers at high prices, further stimulating home production while at the same time, the domestic textile industry continued to import cheaper cotton from world market sources. After three years of massive cotton surplus, storage and management costs became unbearable. Import restrictions, the reduction of domestic cotton prices and exports failed to alleviate the situation, so that the government announced the complete liberalization of the cotton market as from September 1999.

Foreign Trade

Up until the mid-1980s, the export of agricultural products played a crucial role in earning foreign exchange. In recent years, however, the agricultural export share has declined, so that it is no longer of such importance. The concept that grain self-sufficiency is vital to China’s independence is another fundamental issue. In 1996, the government yet again declared its intention of maintaining Chinese grain self-sufficiency at a 95 percent level.

Chinese involvement in international trade grew rapidly from 1978 onwards. Commodity composition came closer to comparative advantage with a major shift away from raw materials to labor intensive manufactured goods. In addition, the export of labor intensive agricultural goods such as fruit, vegetables and meat accelerated.

Following the introduction of the People's Communes, China ceased to be a net grain exporter and became a long-term importer of this commodity. Imports were increased in the early 1980s with a view to reducing the pressure on farmers to produce grain. Sustained expansion of maize production in North-East China helped to reduce the grain deficit, finally making China a net exporter of grain in 1991.

Wheat has accounted for 90 percent of Chinese grain imports since 1961. Indica rice was imported for consumers in the South, while japonica rice was exported to Japan. Soybean exports were also an element of Chinese foreign trade. Increasing maize exports in the late 1980s were not so much the result of a maize surplus in the country as a whole as a reflection of the transport bottlenecks in the Chinese North-South corridor.

The Chinese foreign trade regime consists of three elements: tariffs, licensing and quotas. These measures used to be adjusted annually, giving the government a powerful tool with which to control trade flows. Tariff rates were applied at two levels: a lower tariff for countries with a preferential agreement and another level for all other countries. Since the early 1990s, China has gradually reduced its tariff rates. However, tariff rates for grain remain high. Import quotas are the principal means of controlling foreign trade. Although several import quotas have been abolished, they still apply for grain, edible oils, wool, rubber, sugar, tobacco and fertilizer.

Traditionally, the grain trade has been handled by the state monopoly which is often inflexible. It is responsible for the annual import and export plans and handles trading with quota grain. This has led to a situation whereby trade changes have tended to magnify domestic market fluctuations, e.g. in years when the domestic market price was above world market level, China still exported grain as the state grain traders could export grain they had purchased at a lower quota price.

In spite of certain input subsidies, agricultural products were net taxed between 1993 and 1995. A comparison between the world market and the domestic market level reflects the Chinese import substitution policy: prices for imported products tend to be higher than world market level while those for exported goods are lower.

The People's Republic of China first applied to join the GATT in 1986. Tariff reductions and market orientated reforms gave a new impetus to the negotiations in 1994, and finally led to bilateral agreements with the USA in October 1999 and with the EU in May 2000. Agreements have now also been concluded with most other WTO members.

Industrial countries, such as European Union members or the USA, are demanding improved access to Chinese markets for their industries. At the same time, China expects better and guaranteed access to markets in the industrialized countries for its own manufacturing sectors. In turn, it will be obliged to open its markets and - what is more important - reduce state control of domestic markets. Finally, WTO access will give the government a valid reason for implementing unpopular but necessary reforms in the state sector.

The agreement signed by the Chinese and US delegations in October 1999 foresees that all trade regime changes must be implemented by 2004. These include the reduction of average agricultural tariff rates to 17 percent, the conversion of import quotas into tariff rate quotas and the reduction in state trading by allocating a predetermined share of the tariff rate quotas to private traders.

Central government might well be unable to implement these trade policy reforms in all provinces. It is feared that the new trade regime might increase income disparities between the relatively rich coastal provinces and the less developed inland provinces. To a large extent, farmers in the coastal provinces are already commercialized and benefit from good market access. As a result, they will profit from new export markets abroad. On the other hand, farmers in remote regions might suffer income losses as inefficient marketing and the poor transport infrastructure may well mean that their products are unable to compete with imports in coastal markets. The same might apply to some state owned industries. Under such adverse circumstances, local governments might possibly prove unwilling to surrender market control in their provinces.

As Chinese economic growth progresses, demand for grain - food grain and to a larger extent feed grain - is expected to rise from 375 mil. tons in 1995 to 500 mil. tons in 2010. If China continues to aim for a high level of grain self-sufficiency, the country will probably continue to cover most of its grain requirements. Given sustained technological progress and high investments, there is still the potential to increase yields.

In view of its relative resource endowment - little arable land per capita, low wage rates and low capital intensity – China's comparative advantages lie in the production of labor intensive goods, i.e. textiles, and primary products, i.e. labor intensive cash crops, fruit and vegetables. Liberalization of external trade flows will probably lead to higher exports of these goods, while imports of land intensive products such as wheat, feed grain and rice will rise.

During the past decade, the importance of agricultural exports has declined constantly. If China opens its markets, allowing the economy to benefit fully from comparative advantages, the country may well become a long-term food importer. However, it is expected that these imports will be more than offset by the booming manufacturing industries so that China will be well able to afford to buy the food needed from abroad. However, one key question remains, namely, will China allow this development to take place, or will it embark upon a policy path similar to that adopted by other East Asian countries such as Japan, Korea and Taiwan and switch from taxing agriculture to subsidizing it?

3 Agricultural Inputs

3.1 Overview

This Chapter discusses the development of the use of agricultural inputs, the respective policies and existing constraints.

a. Property Rights, Input Allocation, Investments

Under the People's Communes, the communal organization was responsible for investments in agricultural infrastructure and overall decision-making regarding input allocations. After 1978, farmers were suddenly free to decide the allocation of resources for themselves. To begin with, this led to a significant improvement in efficiency: land unsuitable for crops was taken out of production while higher yields were achieved on the remaining land. Farmers were now motivated to use inputs efficiently, as their allocation had a direct impact on farm income.

Up until the mid-1990s, unstable land tenure policies discouraged farmers from investing in maintaining the long-term productivity of the land they farmed. For example, farmers used their savings almost exclusively to build farmhouses instead of investing in land improvement and crop production. The amelioration of their land tenure rights in recent years may boost farmers' confidence to invest in agriculture.

Although China's government tried to increase both public and private investments in agriculture, the annual investment in agriculture, as a percentage share of total government expenditure, declined steadily until very recently. The "Agricultural Law of the People's Republic of China" of 1993 stipulated that government expenditure on agriculture should increase at a rate higher than the growth rate of government revenue. As a result of this, the government began to pay more attention to agricultural investment and the management of funds for agricultural uses. For instance, the Agricultural Development Bank was founded in 1994 with a view to ensuring better management of funds and loans for agricultural purposes. Its official mandate was to raise funds for loans associated with the implementation of agricultural policy (Tuan and Cheng 1999).

b. Marketing System

Up until the mid-1980s, the distribution of major manufactured inputs was monopolized by the Agricultural Input Corporations at wholesale level and by the Agricultural Supply and Marketing Cooperatives at retail level. Originally, these cooperatives were owned by the farmers, but in time it was the state that took over their control and management. The only items which could be traded without state intervention were intermediate goods produced on the farms and farm tools produced at small rural workshops. Farm machinery was allocated by means of quotas or plans. However, there were frequent supply shortages as prices were subsidized. Chemical fertilizer, pesticides, diesel fuel, plastic sheets and certain seeds were allocated through the central-provincial-county planning channel. A quota system was applied based on production and procurement plans as well as on availability and the acreage to be sown with specific crops (Carter et al. 1996).

Following the urban enterprise reform in the mid-1980s, a two-track price system was adopted to stimulate industrial production. Under this two-track price system, industrial enterprises were assigned production targets as before, with a planned procurement quota which they were bound to sell at a "planned price". In mid-1984, local commercial enterprises were granted permission to purchase farm inputs independently and to sell them at prices in line with their purchase prices plus handling costs and a small profit (Sicular 1993). In this way, above-target output could be sold to the government at a "negotiated price" or onto the market if permissible. It follows that inputs over and above the plan were bought either at negotiated or market prices (Carter et al. 1996). Inputs allocated under plan continued to be sold at prices fixed by the state (Sicular 1993). The quantity of inputs supplied at planned prices was defined, as before, in relation to sown area procurement quotas and farmers could buy additional supplies at either negotiated or markets prices (Carter et al. 1996). These changes in policy resulted in higher average prices for farm inputs. Prices began to rise, especially for diesel oil due to the abolition of subsidies, and for fertilizer following an increase in planned prices (Sicular 1993).

Input price subsidies were abolished in the early 1990s in order to reduce budget subsidies and increase state enterprise profits. They were replaced by direct cash subsidies paid to the farmers. In 1993, the government announced its intention to further reform the farm input market, including the abolition of the two-track price system. The government proposed to pay farmers a fixed cash subsidy for manufactured inputs, while price subsidies were abolished. This change might indeed have had positive effects on allocation efficiency. However, farmers complained that the new strategy would actually lead to a reduction of the support they received. The input price subsidy increased in line with market prices whereas the value of the monetary compensation was a fixed amount (Carter et al. 1996).

Price and marketing policy for agricultural inputs has undergone tremendous changes along with reforms in agricultural commodity policies. Markets for machinery and equipment, pesticides and insecticides, petroleum and diesel have all been liberalized. The production and distribution enterprises of most agricultural inputs have also been granted exemption from value added taxes (Tuan and Cheng 1999).

3.2 Fertilizer

In 1949, most of China's cultivated land was deficient in organic matter and plant nutrients. From the early 1950s, therefore, the Chinese government started to devote some attention to soil fertilization. Of all the technological policies adopted by the government, those dealing with fertilization have been given the most emphasis and are the least disputed. Even today, the government still plays an active role in the production and distribution of fertilizer.

a. Organic Fertilizer

Chinese farmers have drawn organic fertilizer from a wide range of sources such as night soil, animal manure and oil cakes. Night soil and animal manure are the most important sources due to their availability, high nutrient content and low cost. In the 1950s, policy placed emphasis on mobilizing all possible organic fertilizer resources. Chinese farmers applied much more organic fertilizer in the 1950s than in previous decades due to high production incentives stimulated by the 1950 nation-wide land reform and the government's energetic encouragement to improve crop yields. Per hectare application of organic fertilizer increased from 7.5 tons in 1933 to 11.3 tons in 1952 and reached 15 tons by 1957 (Chao 1970). The increased use of organic fertilizer became a key factor contributing to China's rapid growth in grain production between 1950 and 1957, albeit at the expense of a waste of human and natural resources (Wang Q. et al. 1996).

Although the growth rate for organic fertilizer has been steady, it has slowed somewhat since the 1960s and it has been surpassed by chemical fertilizer in terms of total nutrient supply. However, it still plays an important role in Chinese agriculture, especially in regions with low application rates for chemical fertilizer. Since the early 1980s, the government and farmers have been less keen on the use of organic fertilizer. In addition to the increased opportunity costs of organic fertilizer, China's land ownership system has discouraged farmers from using more organic fertilizer due to the fact that its effects on land productivity are somewhat slower and more long-term orientated compared with chemical fertilizers (Zhang W. and Makeham 1992). The development of a land market may encourage farmers to make long-term investments to improve soil fertility (Wang Q. et al. 1996).

b. Chemical Fertilizer

The Chinese government recognized the limitation of organic fertilizer, both in terms of quantity and nutrient content, in the early 1960s and began promoting chemical fertilizers by investing in domestic production, increasing imports and providing price subsidies for farmers. Domestic production and imports of chemical fertilizer were extremely low in the 1950s. They increased steadily in the 1960s and 1970s and have grown rapidly since the late 1970s (SSB SYC 1994). In the 1960s and 1970s, China's domestic chemical fertilizer was produced mainly in small plants, using a cheap process (developed in China in 1962) to produce ammonium bicarbonate (Stone 1986). The small size of these plants and low product quality, coupled with the prices for fertilizer and grain on the world markets, led the Chinese government to import 13 large scale complexes in the mid-1970s and 4 additional large plants around 1980 to produce synthetic ammonia (Smil 1993). Large sums from central and provincial government funds are still being invested to increase chemical fertilizer production (People's Daily 2/10/94). Today, domestic production provides 70-75 percent of the total fertilizer nutrient supply (World Bank 1997).

Table 3-1: Aggregate Fertilizer Application and Grain Yield in China 1952-93

	Chemical Fertilizer (mil. tons)	Organic Fertilizer (mil. tons)*	Total Fertilizer (mil. tons)	Grain Yield kg/ha
1952	0,08	5,84	5,92	1'322
1955	0,23	7,02	7,25	1'415
1960	0,65	7,02	7,67	1'172
1965	1,94	9,87	11,81	1'626
1970	3,22	11,47	14,70	2'011
1975	5,37	13,02	18,39	2'350
1980	12,69	13,76	26,45	2'734
1985	17,76	14,69	32,45	3'483
1990	25,90	16,33	42,24	3'932
1993	31,52	17,66	49,18	4'130

*calculated from NPK content of night soil, animal manure and oil cake

Source: SSB RSY 1994, Wang Q. et al. 1996

The reforms which took place after 1978 have led to rapid growth in China's chemical fertilizer supply and consumption. The growing demand for chemical fertilizer has been a key factor in the increases in fertilizer price and supply. Since farmers' incomes became directly dependent on their productivity, they have made great efforts to improve yields by increasing farm inputs such as chemical fertilizer, adopting new crop varieties, i.e. hybrid rice and improving field management. The positive impacts of the new system became absolutely clear when land contracts were extended to 15-25 years in the late 1980s (Wang Q. et al. 1996).

Table 3-1 reveals that average grain yield and application rates of both chemical and organic fertilizer increased significantly between 1952 and 1993, the rise being particularly significant after 1978. However, the use of chemical fertilizer increased much faster than that of organic fertilizer after the early 1970s and it had become the prime nutrient source by 1982. Nevertheless, organic fertilizer is still a major source of crop nutrient in Chinese agriculture. The use of chemical fertilizer has quadrupled since 1978, spurred on by fertilizer-responsive varieties (World Bank 1997). It has become the major cash input in crop production accounting for 12 percent of total production costs in 1995 (Fan 1997).

Although the recommended nutrient ratio is 100:50:25 (nitrogen, phosphate, potash), China's 1995 application ratio for chemical fertilizer was 100:47:16. A study carried out by the World Bank (1997) showed that in 1995, 6.7 million tons of potash were removed from the soil. This is more than the amount that was applied. At the same time, nearly 3 million tons of applied nitrogen and over 2 million tons of applied phosphate were not taken up by the crops as result of this inequality in nutrient content.

Table 3-2: National nutrient balances 1995

	Nutrient Input*	Nutrient (crop and animal)	Assessed losses	Balance
Nitrogen	32.5	19.5	10.1	2.9
Phosphate	12.5	6.8	3.5	2.1
Potash	12.6	17.5	1.9	-6.7

*Includes chemical fertilizers, crop residues, animal feed, organic wastes, atmospheric deposition and nitrogen fixation.

Source: World Bank 1997

Several studies have shown that a balanced application of fertilizer could increase crop productivity by 12 to 50 percent. One possible reason for this under-application of potash is that in China, the use of fertilizer has evolved on the basis of local supply rather than rather than on an actual needs: since nitrogen is the most abundant locally-produced fertilizer it is also used most. Phosphate application has increased in the last decade, along with the increase of domestic production. However, very little potash is available locally and domestic production is costly.

Official statistics state that the application rate for chemical plant nutrient in 1996 was around 240 kilograms per hectare, which would be one of the highest in the world. An estimated application rate of 155 kilograms per hectare can be assumed, giving due consideration to the 40 percent underestimation of land base and the double counting of single-nutrient fertilizer into compound fertilizer in the region of 10 percent. What this shows is that the fertilizer application rate is below the average for East-Asian developing countries and far inferior to that of Japan and the Republic of Korea. This low application rate may be due to the limited supply. Despite ongoing investments in new manufacturing plants, anticipated capacity increases are unlikely to meet the continuing rise in demand.

About half of China's chemical fertilizer supply consists of low-grade ammonium bicarbonate, single super-phosphate and fused magnesium calcium phosphate. These fertilizers are produced in small factories using relatively simple technologies. Ammonium bicarbonate production is rather energy-inefficient and pollution prone. However, it can be manufactured using anthracite, which is widely distributed throughout the country. Since it is highly volatile, it cannot be stored for long periods. Production is therefore impossible during the fallow seasons. In addition, a high share of the nitrogen applied is lost through evaporation. Single super-phosphate can be manufactured from locally available low-grade phosphate rock using simple, low-cost technology. This low grade material has a correspondingly low nutrient content (less than 20%), which makes transport and handling costly. As not all phosphate is water soluble, it is not immediately available for plant uptake. New factories using modern technology and producing high quality products are under construction. However, they will meet only incremental needs and will not immediately replace the low-grade fertilizer (World Bank 1997).

While spatial distribution of chemical fertilizer was relatively uniform in the 1960s and 1970s, the early 1980s saw a significant change in this situation. In 1992, there was marked imbalance in the per hectare application of chemical fertilizer across the provinces. Application rates in the north-eastern provinces were much higher than those in the north-western provinces. This provincial imbalance reflects proximity to bureaucracy and infrastructure constraints on inter-provincial trade (Stone 1986). Furthermore, chemical fertilizer distribution has been used as a policy instrument to encourage compliance with procurement programs. Frequently, supply was biased in favor of state farms and areas with high crop yields, because more of their output was sold to the state (Stone 1986). Increased fertilizer supplies to areas with low and medium application rates could therefore improve the overall marginal return of fertilizer and reduce groundwater contamination in areas with high application rates (Wang Q. et al. 1996).

c. Fertilizer Marketing and Trade

Up until the mid-1980s, production of chemical fertilizers was centrally regulated and marketing was monopolized by the Agricultural Supply and Marketing Cooperatives (SMC). The government paid significant subsidies for the production and distribution of chemical fertilizers with a view to keeping prices low (Tuan and Cheng 1999).

A dual marketing system came into force after 1985 with a lower quota price and a free market price for above quota production. Once they had fulfilled their plan targets, large and medium-sized fertilizer manufacturers were allowed to sell a certain percentage of their production at market prices. Small fertilizer producers were permitted to sell their products freely. In the early 1990s, the subsidy system for fertilizers was abolished and replaced by direct cash subsidies to farmers. In return, imported fertilizers were exempt from import tariffs (Ke 1998).

While the inflation affecting food was stabilized in 1996, the ongoing rise in fertilizer prices exceeded overall price inflation. Reformers took this as an indicator of the failure of the fertilizer liberalization policy which led to a market retrenchment policy in 1994. The state readjusted factory prices for chemical fertilizers and efforts were made to control fertilizer marketing by trading to a greater extent through the main state channels. In 1995 and early 1996, the provincial governor's responsibility system was introduced for pricing and marketing fertilizers. This meant that the provincial governments were responsible for meeting excess demand for agricultural inputs and maintaining the stability of input prices and government dominance on fertilizer distribution (Huang J. 1998).

Over the last decade, China has imported an average of 8 mil. tons of fertilizer per annum which represents about one fourth of its requirements, and means that the country is extremely dependent on the international market. The major import is urea, followed by potash and compound fertilizer. Consequently, trade policy has a strong impact on the domestic fertilizer price and market. In particular, domestic potassium production is extremely limited. Since about 90 to 98 percent of the potassium used is imported, its use and availability is directly connected to Chinese import policy.

Traditionally Sinochem, a Ministry of Foreign Trade company, has the exclusive right to import fertilizer. However, it lacks flexibility and has failed to respond to demand changes. In particular, potash imports have been too low in the past, which has led to a chronic potash deficit in Chinese soils (World Bank 1997).

d. Fertilizer Productivity

It is assumed that yield response to fertilizer application is a significant factor in Chinese agriculture. It has been observed that fertilizer application rates rose in line with grain yield improvements. Calculations showed that even in 1993 aggregate grain yield response to fertilizer application rate was still positive, although by a decreasing margin.[1] This suggests that enhanced fertilizer application still has the potential to increase yields (Wang Q. et. al. 1996).

An official Chinese calculation indicates that increased fertilizer application accounted that about 40 percent of the growth of total grain output during the period from 1986-90 (Peoples Daily 28/11/91). A study by Fan and Pardey (1995) showed that 22 percent of the growth of Gross Value of Agricultural Output (GVAO) between 1965 and 1993 was attributable to increases in applications of manure and chemical fertilizers. Regional differentiation revealed that the contribution to growth due to fertilizer was higher in Northern and Western China than in the South and central regions. A comparison of the three periods 1965-78, 1979-84 and 1985-93 demonstrates that this contribution declined steadily from 38 percent to 12 percent to 9 percent (Fan and Pardey 1995). Returns for fertilizers fell between 1985-92 as grain prices failed to keep pace with those of fertilizer leading to a decline in productivity (Carter et al. 1996; Widawsky et al. 1998; Huang J. et al. 1997).

3.3 Irrigation

a. Public Investment

Prior to the rural reforms which began in the late 1970s, the Chinese government paid great attention to the building and maintenance of irrigation systems. In the end, major investments by the public sector helped to build one of the largest and most complex irrigation systems in the world. These investments in irrigation facilities have been by far the largest component of total construction investment in agriculture involving sums several times higher than those assigned to agricultural research (Stone 1993).

Up until 1975, real annual expenditure on irrigation rose continuously (Huang J. et al. 1996). In the initial years of the People's Republic, most of the irrigation construction involved locally organized small-scale projects and publicly financed large-scale surface projects (Stone 1993). Labor for local irrigation development was contributed by local residents. In the late 1960s and 1970s, tubewell development encouraged the expansion of irrigated areas (Huang J. et al. 1997).

Development of the nation's water control infrastructure continued during the early 1980s (Huang J. et al. 1997). However, government investment in agriculture decreased dramatically. The abolition of the communes led to a lack of institutions to assume responsibility for local water projects and no investments were made. Private investment in irrigation was minimal due to the absence of long-term property rights relating to farmland. As a result, the maintenance of

[1] Wang Q. et al. (1996) calculated a quadratic function setting time series data of 1952-93 grain yield in relation to fertilizer (chemical and organic) application, time lag and adoption of the Household Responsibility System.

rural infrastructure, including irrigation canals, was neglected leading to serious deterioration of these facilities (Carter et al. 1996).

In response to this situation, expenditure on irrigation began to climb again after 1985, reaching an all time high in 1992 (Huang J. et al. 1996). This period saw the construction of numerous new medium and larger scale water control projects, more in fact than at any time since the mid-1960s (Stone 1993). Although the number of pump sets remained stable, the overall quality of water control equipment was upgraded continuously (SSB AYB 1990).

b. Irrigated Area

China's irrigated areas expanded rapidly between the founding of the People's Republic and 1978. The period 1950 to 1978 was marked by an increase in irrigated area from 16.67 mil. ha to 44.97 mil. ha. This momentum ran down afterwards. In fact, in the early 1980s, there was a decline in the area involved, followed by a recovery after 1985.

The dramatic turn taken by trends in irrigation in the early 1980s coincides with the launching of the economic reform. The reforms weakened the central government's ability to invest in water projects while at local level, the institutional transition from People's Communes to the Household Responsibility System gravely undermined the function of collectives to organize and finance water construction and maintenance. Aging irrigation facilities further exacerbated the situation. Furthermore, in the northern region, the development of irrigation was retarded, in part, by the depletion of water resources which affected many areas.

In the late 1980s, the main increases in irrigated areas were registered in the Northern region while there was little change in the Sough. This was mainly due to the fact that marginal returns on irrigation tended to be high in the North, a situation that was encouraged by the availability of cheap water at a price below market level. Finally, up until 1995, the North's off-farm economy had not developed to the same extent as had the South's, thus keeping agricultural activity more attractive (Yang 2000).

Prior to the 1980s, much of the expansion of irrigated areas had been based on tapping surface water. The use of electrically powered tube-wells to irrigate staple grain crops became common after the late 1970s, and today feeds 28 percent of China's total irrigated area. These wells are concentrated in the North, Northwest and Northeastern Region.

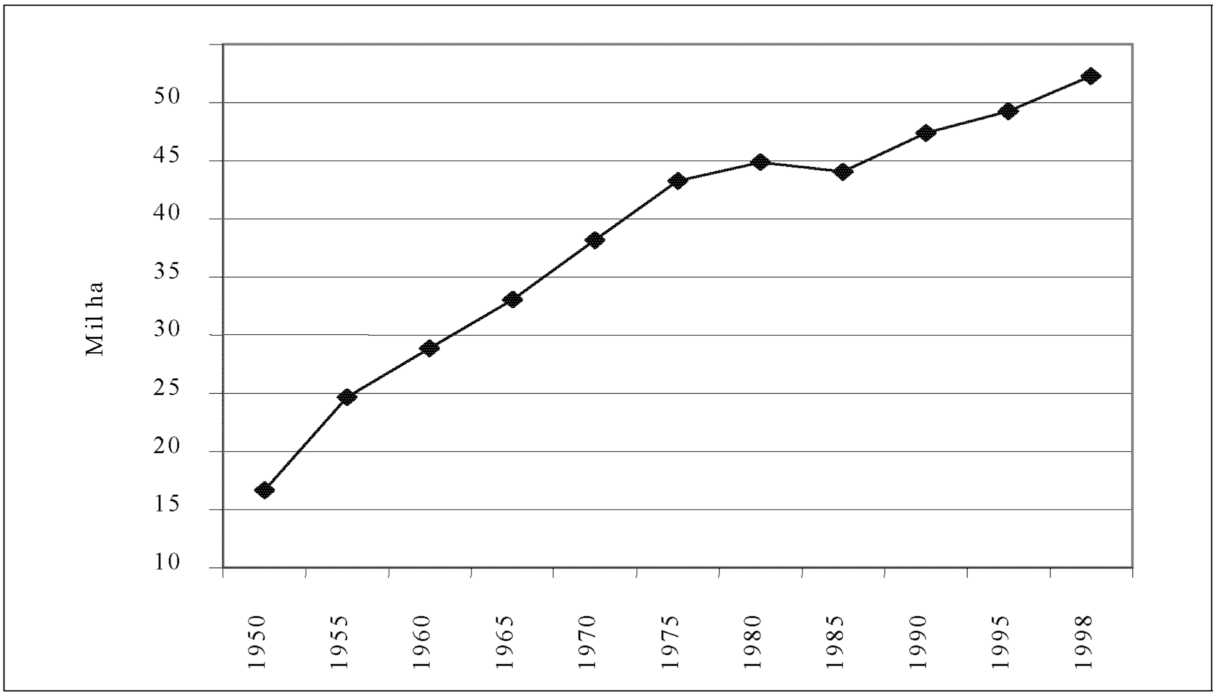


Figure 3-1: Area Irrigated in China 1950-1998

Source: Statistical Yearbook of China, in Yang 2000

c. Water Use

The total volume of water used has increased in line with economic growth and improvements in the standard of living. Between 1980 and 1997, total water withdrawal increased 27 percent from 443.7 bil. m^3 to 562.3 bil. m^3. This growth was approximately in line with population growth. While the effective irrigated area rose during that period from 45 to 50 mil. ha, there was only a slight change in the volume of water used for irrigation, namely from 358 bil. m^3 in 1980 to 369 bil. m^3 in 1997, indicating a decline in the average water use per unit of irrigated land.

The share of irrigation in total water withdrawal declined from around 80 percent to 66 percent during the same period (MWR 1998).

d. Contribution to Growth

Public investment in irrigation has been an important determinant in China's agricultural growth in recent decades (Lin 1992). Huang J. et al. (1997) showed that between 1978 and 1992, public investment in irrigation contributed 5 percent to the total rice growth rate and 6 percent in the case of other grains. In addition, irrigation was a major factor in increasing the cash crop output growth by 35 percent.

On the other hand, real expansion of irrigated area has not made a similar contribution to growth in recent years. Fan and Pardey (1995) showed that it was only prior to the 1965-78 reforms that irrigation's contribution to the growth of

Gross Value of Agricultural Output amounted to 9 percent. In fact, irrigation's contribution to agricultural production was negative after 1978.

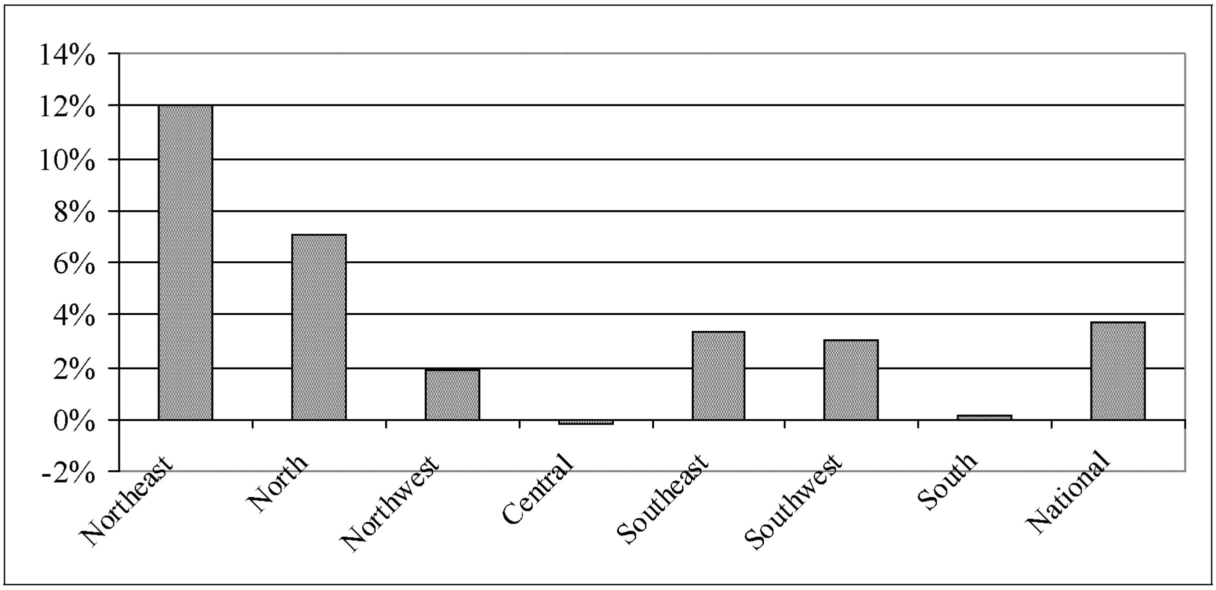


Figure 3-2: Contribution of Change in Irrigated Area to the Growth of the Gross Value of Agricultural Output 1965-93

Source: Fan and Pardey 1995

This underlines the hypothesis that the neglect of the irrigation system following the abolition of the co-operatives led to a reduction in agricultural production. However, a number of the improvements in irrigation were generated by increases in infrastructural aspects, such as the mechanization of many irrigation facilities. The increase in mechanization contributed positively to growth, even after 1978 (Fan and Pardey 1995). According to Huang J. and Rozelle (1995a), the contribution of the increased irrigated area to grain yield was a negligible 0.4 percent from 1975-90.

The contribution of irrigation to GVAO growth between 1965-93 in the various agricultural regions differs considerably: The country average of 3.7 percent was exceeded noticeably in the Northeast and North (12,0%, 7,1%), about average in the Southeast and Southwest and much lower in Northwest, Central and South China (1.9, -0.2%, 0.1%) (Fan and Pardey 1995).

e. Water Shortage in Northern China

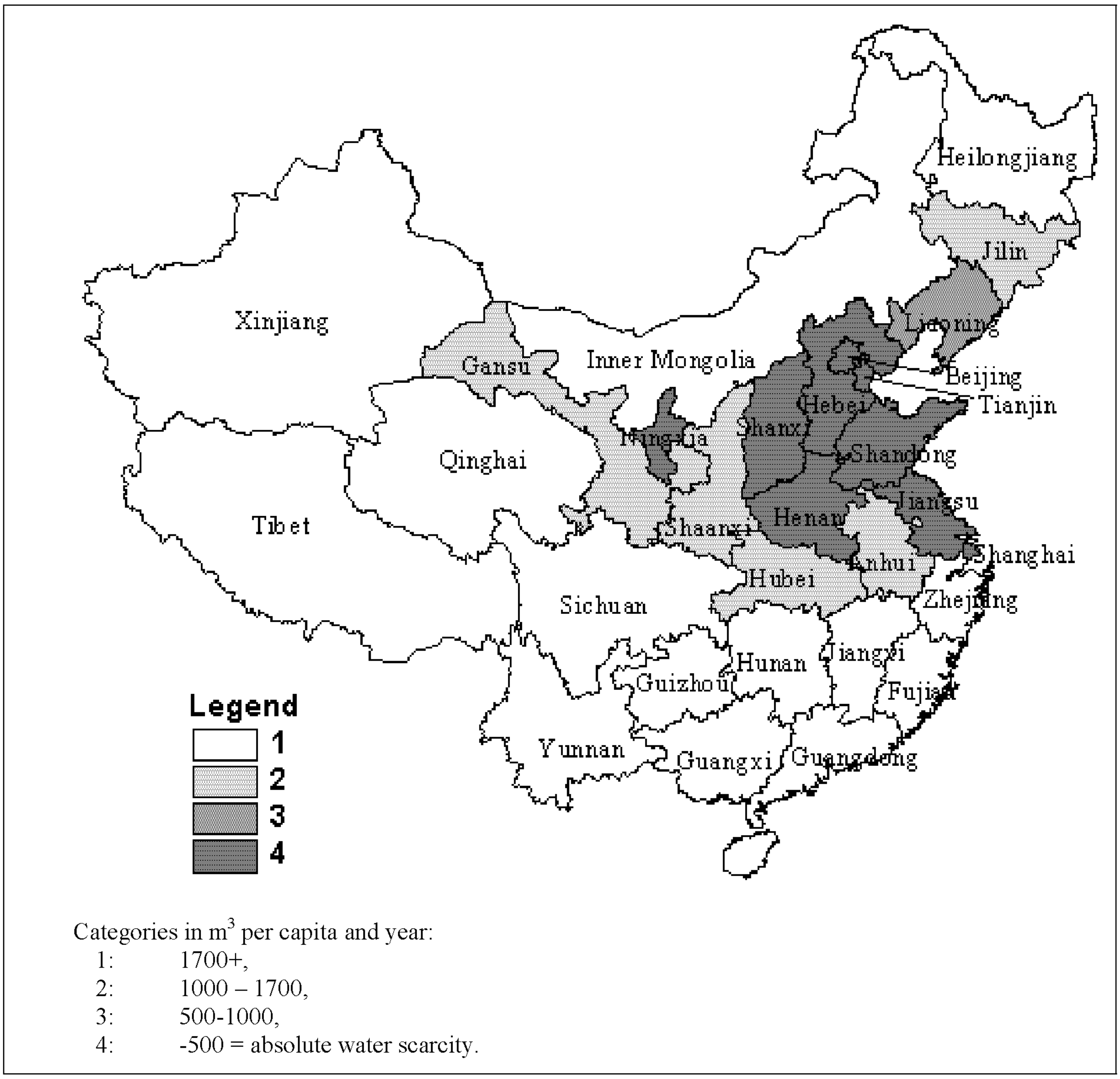


Figure 3-3: Per Capita Water Availability by province 1998

Source: Yang 2000

As illustrated in Figure 3-3, water distribution differs considerably across the regions. Shortages center on the northern regions, particularly the Huanghe, Huaihe and Haihe water basins while water is relatively plentiful in the rest of the country. Consequently, the nation as a whole is expected to have enough water to meet its requirements over the next 10 to 30 years if it can build facilities to tap it. However, the northern region faces severe problems that are likely to become even more serious in the future. Although it has less than 20 percent of China's water resources, 67 percent of the cultivated land is concentrated in the northern region. Since precipitation is generally inadequate, irrigation is absolutely essential if high yields are to be achieved in this region.

In the Huang-Huai-Hai Region, water scarcity has constrained the expansion of irrigation and led to a depletion of groundwater aquifers. The potential for further tapping of surface water is only marginal. In many areas, newly drilled wells merely serve to replace those which have dried up completely and been abandoned. Any expansion of irrigation which relies on diminishing ground water aquifers can therefore only be short-lived. Due to increasing competition from non-agricultural sectors, water resources available for irrigation are expected to decline even further. The only source for irrigation expansion lies in improving water use efficiency within irrigation networks. The building of a South-North water diversion project is unlikely to alleviate the problem substantially (Yang 2000).

In response to the increasing water problem in northern China, some medium- and large scale water projects have been set up to tap stream water within the basin and to transfer water from areas where there is an abundant supply to areas where there is a deficiency. In addition, a number of mega-scale water projects have been launched or are about to get under way. However, irrigation has a very small share in these large water projects. None of the larger water projects currently planned or under construction are aimed at increasing irrigation. Invariably, the municipal and industrial sectors have been given priority. There are two reasons for this which are worthy of mention:

the economic return on each unit of water used in agriculture is lower than that earned in the urban sectors[2],

administered prices for water used for irrigation are lower than the price for water used for other purposes. This gives the local population an incentive to divert water from irrigation to other sectors while paying the same price for the water as agriculture.[3]

At the moment, water use efficiency is generally low. It has been estimated that the efficiency of the irrigation network lies at a mere 40-50 percent and in some areas is as low as 30 percent. However, this water is not entirely lost since it is available again to users further downstream. Therefore, although there may be considerable potential for improving water use efficiency in the case of individual schemes, the potential for the water basin as a whole could well be modest (World Bank 1999), although still in the region of 10 to 20 percent (Yang 2000).

There is a consensus that low water prices provide little incentive for farmers to adopt water-saving technologies. The pricing of irrigation may therefore help

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2 E.g. The economic benefit of water transferred by the South-North Water Diversion Project is estimated at 0.99 Yuan per m^3 for industrial and municipal sectors and 0.56 Yuan per m^3 for irrigation (ECCAY 1997).

3 In the South-North Water Diversion Project, the average price for industrial water use is set at 0.31 Yuan per m^3, while that for agriculture is only 0.06 Yuan per m^3 (ECCAY 1997).

to improve irrigation efficiency. Given the relatively high share of irrigation costs in the total cost of grain production, an increase in the price of water is likely to have a significant impact (effect) on farmers' production decisions. One response would be to adjust crop structure to increase the output value per unit of water i.e. a shift from grain, mainly wheat, to high value cash crops. This shift would be in line with the comparative advantages of Chinese agriculture, but counter to the government's goal of maintaining China's self-sufficiency in grain production. A compromise could be to replace wheat with corn, as corn has a higher water utilization efficiency (Yang 2000).

3.4 Labor and Land

Compared with other countries in the world, China has one of the lowest arable land areas per capita. Consequently, the Chinese government has made consistent efforts to expand the area of arable land by reclaiming land previously not used for agricultural purposes. Other measures have included: increased yields on existing land by expanding irrigation; the introduction of high-yielding varieties coupled with an increase in fertilizer and other inputs; the expansion of the sown area by reducing fallow periods; the change from single to double cropping in the North; the change from double to triple cropping in the South.

a. Arable Land and Sown Area

The principle development trend for arable land displays a moderate decrease, reflecting ongoing urbanization. In 1994 the government introduced policy measures to designate arable land and prohibit conversion by releasing a regulation for arable land conversion. There is still considerable potential for developing arable land, mainly in frontier districts in the North, namely the Inner Mongolia Autonomous Region in Heilongjiang province, which has a potential of 14.7 mil. ha convertible wasteland. This could even offset further urbanization (Ikegami 1997).

In the past, sown areas were increased by shortening the growth period per crop. This allowed several harvests per year (multiple cropping). Although multiple cropping is still promoted by the government, rising labor costs have led to a decline of this practice in economically well developed areas (Fan 1997a).

Total arable land has declined steadily since the 1950s. In the main, it has been sacrificed to water projects and industrial and urban construction. The total sown area has varied. While the area of cultivated land dropped by 0.2 percent annually in the early 1970s, the sown area increase by nearly 1 percent per year due to increased cropping intensity. After 1978, the trend was reversed and the sown area fell for 10 years following the start of the reforms. The sown area reached a low point in 1988 and then rose through 1992 (Huang J. et al. 1997).

Under the Communal System, the allocation of production surface was planned according to procurement quotas. The introduction of the HRS allowed farmers to allocate their land freely, as long as they met the procurement quota. As a result, marginal land was taken out of production. Farmers started to diversify production in line with the given incentives. Between 1978 and 1992, the area sown with grain registered a net decline of 0.5 percent per year. Most of the decline took place in the early 1980s.

b. Farm Size

The transformation of People's Communes into single family farms led to marked fragmentation. For example: a production team with a plot with 18 ha was divided into 30 farms constituting of 4-5 plots each. In the end, the size of an average farm amounted to 0.5 ha with 2-3 family workers each.

It is widely recognized that these small plots cannot produce efficiently as economies of scale are lacking. For example: in Jiangsu province the typical farm size is 0.15 to 0.16 ha or less than 0.1 ha per worker. In this environment, an experiment showed that the right farm size to ensure an income equivalent to that of a worker in a rural township or village enterprise would be 1-2 ha per worker, with initial investments necessary.

The government has tried to introduce measures to activate economies of scale. But attempts to reconsolidate land and thereby reduce the number of plots have not been effective. Moreover, they provoked conflicts between farmers. In order to avoid these disputes, farmers have been permitted to subcontract plots. Certain services, such as machinery and pest control, have been carried out collectively within a so-called two tier system. Special production associations have been established in the cash crop and animal production sectors. These associations provide technical services and manage the marketing of the products. In contrast to the two tier system, association members can come from different farms. In some coastal areas, voluntary production and marketing co-operation have been introduced which have benefited from economies of scale. These attempts have not been able to change the fact that average farm size is too small and that the labor force in farming is too high (Carter et al. 1996).

The cases of Japan, South Korea and Taiwan show that over two thirds of their farms operate on less than one hectare (Rosner 1994). Compared with China, the only difference is that their agriculture receives government subsidies and off-farm income is significant in Taiwan and Japan. Experience gained in these countries shows that even with free transferability of land, effective land transfers are infrequent. Therefore, from a long-term point of view, small-scale farming will remain the dominant structural characteristic of Chinese agriculture (Carter et al. 1996).

c. Labor Surplus and Migration

In the early 1950s, the strategy adopted by the communist government gave the development of heavy industry top priority. To implement this strategy in the capital-deficient economy, the government introduced a package of policies to reduce the production costs of heavy industry. This distorted the prices of commodities and the basic factors of production. Urban labor costs were reduced by a "cheap food" policy and urban housing subsidies. This urban-biased regime was supported by the commune system which tightly controlled farm-worker migration, thereby preventing workers from moving into the cities. In addition, the government introduced a household registration system (Hukou) under which the rural population was treated differently to urban dwellers. This limited the number of subsidized urban residents since the system prevented peasants from changing their occupation or place of residence. Even though there was already a labor surplus at that time, the problem was not very conspicuous. Due to lack of supervision and incentives to work, it was common for people to go to work but do nothing.

Under the communal system, the deployment of the labor force was organized by the heads of the Production Teams. Labor was allocated according to plan rather than for reasons of efficiency. In the 1950s, 1960s and early 1970s, this situation was sustained by the mandatory procurement policy and government planning which forced the communes to use increasing amounts of labor for grain production (Huang J. et al. 1997). The switch from the Communal System to the Household Responsibility System gave the farmers incentives to use their labor more efficiently. In addition, they could now decide freely on how to use their labor once they had fulfilled their procurement quotas. The procurement system is still in force today obliging farmers to devote a certain share of their labor force to the production of procured products. The government therefore still can influence labor allocation in agriculture to a certain extent, e.g. in 1993, 40 percent of the Chinese agricultural workforce was still engaged in grain production (Carter et al. 1996).

The surplus became obvious with the more effective use of labor. At the same time, enhanced opportunities in the non-cropping and off-farm sectors led to large shifts of labor away from agriculture. This development was encouraged by the wage gap between agriculture and other sectors (Huang J. et al. 1997).

China's farming system is, by nature, relatively labor intensive and therefore requires lower fixed-capital investments. Since the character of the industrial sector is less sophisticated, the reallocation of workforces among other sectors is not a costly operation (Huang J. et al. 1997). Booming Township and Village Enterprises (TVEs) absorbed excess agricultural labor and tens of millions of workers found employment in the emerging industrial and commercial sectors, although this applied mainly to skilled labor. Between 1978-1993, the annual increase in TVE employees amounted to roughly 13.1 percent. Thus, by 1994 123.45 mil. former farmers were engaged in TVEs which meant that the share of labor employed in agriculture had steadily declined, from 70 percent of the national total in 1978 to under 60 percent in 1993.

In recent years, increasing labor costs and stronger competition has forced TVEs to switch to more capital intensive production. The future growth of TVEs will therefore probably not permit them to absorb as much excess labor as they have done previously (Carter et al. 1996).

Since the economy has grown faster in the cities and coastal areas, more workers from the interior have poured into these regions to find employment. The large numbers involved, many of them transient workers,[4] have contributed to problems of rising unemployment and crime rates in urban areas, as well as placing additional burdens on public utilities (Carter et al. 1996). In order to maintain social stability, certain barriers have remained in force, discriminating between the urban and rural population from the Communal System. This discrimination against rural immigrants applies to access to employment, free medical care and education, subsidies for public transport utilities and, most important of all, access to subsidized housing[5] (Wu H. X. 1994). These restrictions helped have helped to slow of migration and prevented migrant workers from settling in the cities.

However, it has been estimated that there is a surplus of some 100-130 million[6] agricultural workers. When the adjustment of the rural labor-force in China is compared with that of other East Asian countries it can be seen that, in spite of official barriers, Chinese agricultural labor has adjusted rather fast (Huang J. et al. 1997).

3.5 Factor Productivity

a. Land and Labor Productivity

Craig et al. (1997)[7] compared agricultural land and labor productivity (crops and livestock) in ninety-eight countries and thirteen geopolitical regions for the period 1961-1990. According to this study, Chinese labor productivity is the lowest in the world. This would seem to be typical for the Asian and Pacific region as both regions have the lowest land/labor ratio in the world. Only Sub-Saharan

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4 In 1992, approximately 35.75 mil farmers lived temporarily in cities and towns (Ministry of Agriculture, Research Centre of Rural Economy 1993).

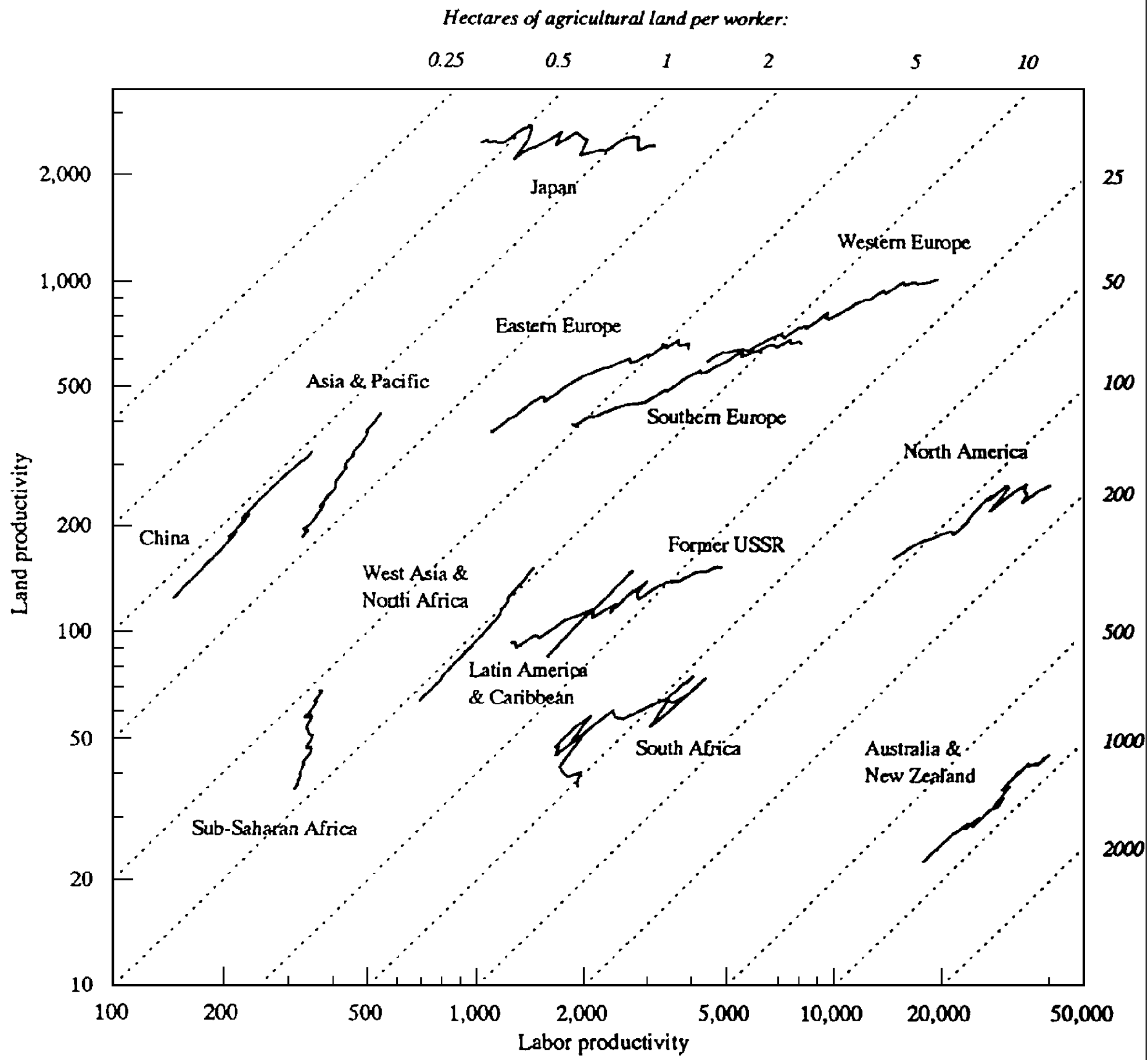
5 Most cities suffer housing shortages which makes it almost impossible for poor immigrants to find accommodation they can afford (Lin 1991, Lyons 1992, Rozelle 1994).

6 The Chinese Minister of Agriculture and several other publishers estimated that one-third of the 438 million rural workers are surplus. Taylor (1993) found evidence that 30-40 percent of China's rural workers were redundant i.e. about 100 million persons. Calculations in Carter et al. 1996 resulted in an agricultural labor surplus of 139 to 170 million workers, 50 to 100 mil. of whom are rated as floating population.

7 Applying an Multivariate Regression model with a Cobb Douglas production function, they considered land and labor quality, fertilizer use, tractor and animal horsepower use, livestock breeding, road density, and research expenditures as a source of productivity differences.

Africa exhibits a comparably low labor productivity. In comparison with other developing countries, Chinese land productivity is quite high, roughly equaling that of North America, but lower than that of the Asian and Pacific region. Land productivity in Japan, where farms are about the same size as in China, is roughly ten times higher. China has one of the world's highest labor intensity/land ratios in agriculture. Compared with the Asian and Pacific region, where labor per hectare has increased substantially during the last 3 decades, the land/labor ratio has remained virtually stable in China.

A substantial share of the international (cross-country) variation in output per worker can be attributed to differences in the use of conventional inputs. The regions with the highest output per hectare, Asia and Europe, are among the heaviest users of fertilizer. The regions with the lowest output per hectare, Australasia and Sub-Saharan Africa, use far less fertilizer per hectare than the other regions. In addition, the regions exhibiting the lowest tractor horsepower per hectare are sub-Saharan Africa and Australasia, which at the same time are the regions with the lowest levels of land productivity. Those regions with the highest amount of tractor horsepower per worker - North America, Western Europe and Australasia exhibit the highest levels of output per worker. Animal traction



- Graphical techniques used by Hayami and Ruttan (1985)
- Real output per hectare and real output per worker in natural logs
- Vectors moving in north-eastern direction
- Diagonals: constant land-labor ratios A productivity path that crosses a diagonal from left to right indicates an increase in the number of hectares per worker
- See source for List of Countries included in groups.

Figure 3-4: International Comparison of Land and Labor Productivity by Region 1961 to 1990

Source: Craig et al. 1997

represents a high share of total traction in those countries with low labor productivity.

Road density and real agricultural research expenditures have uniformly positive and significant effects on labor productivity. Europe, Australasia and North America are the regions with the greatest research spending per worker, the highest literacy rates and longest life expectancy and exhibit the highest measured land productivity. The regions with the highest levels of output per worker, Japan and Western Europe, have the greatest road density. This may be indicative of the direct effects of research and transport on productivity, although these variables may simply be proxies for a broader set of public resources targeted at the rural population. In particular, it appears that fertilizer use and tractor horsepower are highly correlated with real research expenditures. Animal livestock used in production is associated with higher labor productivity. On the other hand, higher use of animal horsepower for traction is associated with lower output per worker. Higher life expectancy is also associated with higher labor productivity (Craig et al. 1997).

b. Total Factor Productivity

The reforms in Chinese agriculture brought a substantial increase in total factor productivity. However, total factor productivity slowed down substantially during the second phase of the reforms between 1985 and 88, only to revive during the following years (Fan 1997).

Total factor productivity increased slowly but steadily during the first five-year plan period 1953-1957, due to both institutional and technological changes. Peasant resistance to the new policy of the Great Leap Forward between 1958-61 led to a sharp decline in both production and productivity. Agricultural production recovered between 1962 and 1965 thanks to a series of adjustments implemented by the government. Production and productivity were depressed once again during the Cultural Revolution Period 1966-79 as a result of inappropriate policies. Inefficiency was rampant in agricultural production due to the lack of incentives for farmers. Production grew 3.8 percent, but there was almost no gain in total factor productivity. Most of the growth originated from increased input use.

The initial phase of the reforms (1980-84) improved technical efficiency by decentralizing production and raised allocation efficiency by means of price and marketing reforms. The introduction of the Household Responsibility System gave farmers the opportunity to respond to market conditions and adjust their production accordingly. Production growth declined after 1985 due to losses in productivity brought about by diminishing returns from chemical fertilizers, limited opportunities for farm expansion and reduced government investment in agriculture (Zhang B. and Carter 1995).

Agricultural production and productivity began to rise rapidly after 1988 due to increasing market liberalization and achieved growth rates of 5.9 percent (production) and 3.9 percent per annum (productivity) (Fan 1997).

A comparison of the annual growth of aggregate output, input and total factor productivity makes it clear that most of the growth in prereform eras (before 1980) originated from an increase in input use. After the reforms, the contribution of the increase in total factor productivity to aggregate agricultural growth was over three times greater than that attributable to an increased use of inputs (Fan 1997).

Table 3-3: Growth in Input, Output and Total Factor Productivity

	Output	Input	TFP
1953-57	3,6%	3,0%	0,7%
1958-61	-8,5%	-0,4%	-7,3%
1962-65	9,5%	4,9%	4,2%
1966-79	3,8%	2,9%	0,8%
1980-84	6,6%	1,5%	5,3%
1985-88	2,5%	0,8%	1,6%
1989-92	5,9%	2,1%	3,6%
1993-95	8,5%	0,7%	7,7%
1953-79	2,8%	2,7%	0,1%
1980-95	5,8%	1,3%	4,4%

Source: Fan 1997

Summary

Overview

Under the communal system, all inputs were allocated by a monopolized, hierarchical system of Agricultural Supply and Marketing Cooperatives according to sown area plans and production quotas. The introduction of the Household Responsibility system in the early 1980s enabled farmers to use their inputs more efficiently.

From the mid-1980s, the emergence of free input markets allowed state owned enterprises which manufactured inputs to sell their above-target production at higher "negotiated" prices to state traders or other input traders. Farmers still received a certain quantities of inputs at a lower planned price as well as having the opportunity to buy additional amounts at a higher "negotiated" or market price. In the years following the liberalization of the machinery, pesticides, petroleum and diesel markets, market control was replaced by input price subsidies which, in turn, were replaced by direct subsidies in the early 1990s. All in all, these adjustments have led to higher input prices for farmers.

Unstable land tenure rights discouraged farmers from making long-term investments in agriculture. The situation has improved recently since land contracts are guaranteed for a longer period. In addition, up

until the early 1990s, there was a steady decline in the share of total public investment devoted to agricultural purposes. This situation has improved somewhat since the introduction of the new agricultural law in 1993.

Fertilizer

In the 1950s and 1960s China's main source of fertilizer was drawn from organic sources, namely night soil, animal manure and oil cake. Chemical fertilizer supplies increased gradually from the early 1960s onwards due to accelerated imports coupled with continuous investments at provincial and central government levels. Initially, small fertilizer plants were set up and later large scale complexes were imported from the mid- 1970s and early 1980s. The fertilizer industry continued to expand during the 1980s and 1990s. Nevertheless, approx. 25 percent of the chemical fertilizers used in China are still imported.

The government sought to replace the small scale ammonium bicarbonate and single super-phosphate manufacturers with a view to improving overall fertilizer quality and production efficiency. However, these factories continue to operate as their technology is cheap, simple to handle and less capital intensive.

The expansion of chemical fertilizer application developed in line with the introduction of improved seed varieties and contributed considerably to increased grain yields. 22 percent of the growth of the Aggregate Agricultural Output Value between 1965 and 1993 is felt to be attributable to increased application of organic and chemical fertilizer. The demand for fertilizer accelerated significantly when farmers' incomes became directly dependent on crop yields. Overall chemical fertilizer use rose from 13 mil. tons in 1980 to 31 mil. tons in 1993. Fertilizer use is, however, biased: while the use of nitrogen and phosphate is quite reasonable, the use of potash is inadequate. This is mainly due to a lack of domestic supply as local potash production is very minor and imports have been restricted. Recent estimates of Chinese fertilizer use also showed that nitrogen and phosphate application rates are below the average for East-Asian developing countries. In addition, fertilizer application rates are unevenly distributed across the country. This suggests that increasing fertilizer application can still have a positive impact on agricultural output.

Like other manufactured inputs, fertilizer marketing was controlled by the Agricultural Supply and Marketing Cooperatives and was gradually liberalized after the mid-1980s. In the early 1990s, fertilizer price subsidies were abolished and replaced by direct cash payments to farmers. Since quota prices for fertilizer had been too low, they began to rise as soon as markets were liberalized. As in the case of grain liberalization, central government interpreted this as market failure and reintroduced administered factory prices and state control of fertilizer marketing. The introduction of the provincial governors' responsibility system transferred the task of meeting fertilizer demand and maintaining price stability to the provincial governments.

Irrigation

Sustained investment in irrigation infrastructure helped has helped China to build one of the largest and most complex irrigation systems in the world. The area under irrigation has expanded continuously, with the exception of a period of stagnation in the 1980s due to the transfer of responsibilities following the abolition of the People's Communes. In recent years, the expansion of irrigation has been concentrated mainly in the North, due largely to the fact that water scarcity drastically inhibits agricultural production in this part of the country.

Prior to 1980, most of the expansion in the irrigated area was realized by tapping surface water. In the meantime, irrigation from electrically powered tube-wells has gained importance and now accounts for 28 percent of the total irrigated area.

Water demand for non-agricultural uses developed in line with economic growth and ongoing population build-up, namely from 20 percent in 1980 to 33 percent in 1997.

As a whole, China has enough water to cover its needs for the next three decades. However, the North has suffered from severe water shortages in recent years. The tapping of surface water has reached its limits and the expansion of irrigation by tube-well pumping has led to widespread depletion of groundwater aquifers. This situation is unlikely to ease as non-agricultural water demand is expected to increase in the region.

However, there is a certain potential for improving irrigation efficiency by 10 to 20 percent. The government is currently investing in small, medium and large scale water projects to transport water from the South, where water is abundant, to the North China plain. As the price of water for irrigation is much lower than for urban use, it is unlikely that newly acquired water will be sold to agriculture. Any increase in water prices for agriculture would force farmers to irrigate more efficiently, but might well provoke a switch in production away from grain towards high value cash crops.

Labor and Land

Total arable land declined steadily from the 1950s onwards. In the main, it was sacrificed for water projects and construction. Due to enhanced cropping intensity, the sown area increased up until 1978. It declined after the introduction of the Household Responsibility System when farmers abandoned unprofitable production activities and took marginal land out of production.

The abolition of the People's Communes led to extreme fragmentation of farmland. Average farm size is now 0.5 ha cultivated with a labor-force of 2 to 3 workers. In many cases, the land is divided again into several plots. Government efforts to promote the creation of voluntary co-operations has helped to improve the situation somewhat but has not been able to alter the fact that the labor-force employed in farming is too high. However, when the Chinese farm structure is compared with that of other East Asian countries such as Japan, South Korea, or Taiwan it becomes clear that this small scale farming is typical for the region and that the situation is unlikely to change substantially, even with ongoing economic development.

The Chinese development strategy dictated that urban workers were paid low salaries while receiving subsidized food and housing. At the same time, the household registration system prevented the rural population from moving into urban areas.

There was already a surplus of agricultural labor under the People's Communes, but it was not immediately apparent since labor was not allocated for reasons of efficiency. In line with sown area plans and procurement quotas, a large proportion of the labor-force was assigned to grain production.

The labor surplus became evident following the introduction of the Household Responsibility System. While approx. 120 million people found jobs in the emerging rural industries, farmers endeavored to raise their incomes by diversifying their production. However, procurement quotas still forced them to devote a considerable amount of their time to the production of less profitable grain crops.

The booming economy in the cities drew rural underemployed to urban areas in the hope of finding better incomes. However, urban governments enforced a discriminatory policy against the rural migrants by refusing them access to public services and subsidized housing. The situation has deteriorated since the urban state owned industry sector has been instructed to achieve profitability. It is estimated that there is still a surplus of 100 to 130 mil. agricultural workers.

Factor Productivity

Between 1961 and 1990, China had one of the lowest labor productivity rates in the world though it is true to say low labor productivity is typical for countries in the Asian and Pacific Region. The labor/land ratio is extremely high, land productivity resembles that of the USA, but is lower than that of other countries in the region. Both land and labor productivity has grown substantially during the last 30 years. The high level of land productivity is correlated to a large extent with elevated levels for inputs, such as fertilizer, machinery and research expenditures.

Between 1953 and 1979, the growth of aggregate agricultural output was accompanied by equivalent increases in input use. Output growth for the period 1980 to 1995 was three times higher than increases in the input sector. This can be attributed to improved efficiency following the introduction of the Household Responsibility System coupled with the adoption of improved seed varieties.

4 Seed Sector

The Chinese government's overall goal has been to increase agricultural production and therefore the development of improved seed has been rated as a high priority since the early 1960s. Up until 1992, the national seed plan dictated the course of the Chinese seed sector to a large extent. Public research institutes developed new varieties and passed them on to the state-owned seed companies which produced planned quantities at planned prices. This system was abolished in the early 1990s and replaced by a pseudo-market system. Within this framework, research units and seed companies were authorized to operate as commercial enterprises. However, various price and market restrictions inhibited the emergence of a competitive market. Today, Chinese seed policy is ambiguous: on the one hand, the government recognizes the need for continued seed improvement and helps to promote the introduction of biotechnology in agricultural research. On the other hand, the seed sector is highly inefficient since both research institutes and seed companies are suffering under the reforms that have forced them to restructure and, at the same time, their operations are inhibited by ongoing regulations.

This chapter provides an overview of the Chinese seed sector. The structure of the public research system, its research activities and output are discussed in the first section while the following part examines the situation of seed producing enterprises and overall seed market conditions. The final part deals with agricultural biotechnology.

4.1 Public Research

a. The Public Research System

Agricultural research is primarily the domain of the public sector research system, which is sub-divided institutionally into national, provincial and prefecture levels. Herein research is carried out by the Chinese Academy of Agricultural Science, provincial agricultural colleges, local government and agricultural universities (Huang J. et al. 1996). While the national institutes concentrate on basic research, provincial facilities focus on applied and adaptive research and development. The local institutes deal mainly with local production problems (Fan and Pardey 1995).

In 1993, the Chinese agricultural research system boasted 62'800 agricultural scientists and over 32'000 technical support staff and was the largest of all the country's public-sector research systems. However, this vast number of scientists camouflaged the fact that only 5 to 6 percent of these researchers held a postgraduate degree, as compared to 60 to 70 percent in other less-developed Asian countries. 14 percent of the scientists and engineers (excluding university personnel) were based in national institutes, 51 percent in provincial institutes and 35 percent worked at prefecture level. The share in research activities held by universities was a mere 6 percent in terms of researchers and 2 percent in terms of expenditure in the 1960s. There was a certain degree of growth, namely to 19 percent and 6.7 percent, respectively, by the early 1990s, but the share held by these facilities is still minor. As a rule, the regional distribution of agricultural research personnel and expenditure is congruent with agricultural output, population and arable land, with some bias to the Northeast and Northwest region. National institutes are located mainly in the eastern part of the country (Fan and Pardey 1995).

b. Research Expenditures

Growth in agricultural production has been accompanied by an ongoing increase in the human and financial resources devoted to developing the agricultural research system. In the 1950s, agricultural research expenditure was very low. It started to rise rapidly after 1961 and reached a sustained annual expenditure growth rate of 5.7 percent in the 1960s and 1970s. At the same time, the increase in research personnel was even higher, namely 7.3 percent per year (Huang J. et al. 1997). Research was neglected for a while after 1985 and annual expenditure sank between 1985 and 1990, to be followed by a revival of interest in the early 1990s (SSTC 1993). Between 1961 and 1990, financial investment in agricultural research rose nearly fourfold in real terms (Huang J. et al. 1997) and the number of scientists and technical support staff in the national agricultural research system experienced a sevenfold increase (Fan and Pardey 1993). In the early 1960s, agricultural research intensity (ARI)[1] was already above the average for less-developed countries. Even during the Cultural Revolution in the second half of the 1960s, China maintained a substantial level of agricultural research investment. Research had risen significantly in several developing countries, particularly in Asia, and by the mid-1980s, Chinese expenditure was slightly below the average for developing countries and less than one-quarter of the average for developed countries (Fan and Pardey 1995).

Huang J. et al. (1997) calculated that research stock[2] rose sharply during the period between 1955 and 1989. The cutback in research expenditure during the late 1980s curbed the growth of overall research stocks in the 1990s. However, this does not necessarily imply a reduction in research output since research, per se, does not correlate directly with expenditure (Huang J. et al. 1996).

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1 The ratio measuring agricultural investment relative to a Agricultural GNP.

2 Research expenditures multiplied with a lag variable and timing weights.

Table 4-1: Annual Government Expenditure and Stocks in Agricultural Research in China, 1955-1990 (in mil real 1985 Yuan)

Year	Expenditure	Stocks
1955	44	-
1960	328	-
1965	333	-
1970	411	238
1975	510	287
1980	779	407
1985	1038	572
1988	916	695
1990	892	789

Source: SSB SYC 1993, SSTC 1993, SSTC 1991 in Huang J. et al. 1997

c. Impact of Research Expenditure on Agricultural Growth

Fan and Pardey (1995)[3] analyzed the direct effect of agricultural research expenditure on total agricultural production (GVAO)[4] and found that the research payoff was extremely high prior to 1978, contributing 25 percent to total growth between 1965 and 1978. Although this contribution to growth declined to 19 percent from 1979 to 1984 and 14.1 percent between 1984 and 1993 it still remained high.

However, elasticity figures[5] suggest a massive increase in the adoption of technology after 1978 (Fan and Pardey 1995). Regional disparities in the contribution achieved through research expenditure revealed a balanced share of GVAO growth between 1965 and 1993. Given a national average of 19.5 percent, public research expenditure had a much higher influence on agricultural

3 Fan and Pardey (1995) examined different factors such as labor, land, fertilizer, mechanical and animal power, irrigation research expenditure and the impact of reforms as a source of growth of the GVAO in China between 1965 and 1993.

4 GVAO = Total production value of farming, animal husbandry, fishery, forestry and sideline production.

5 1965-78: 20.9%, 1979-84: 30.4%, 1985-93: 37.4%.

output in South China (28,1%) and Southeast (21.1%). The impact was noticeably lower in the Northwest, namely a mere 16.3 percent (Fan and Pardey 1995).

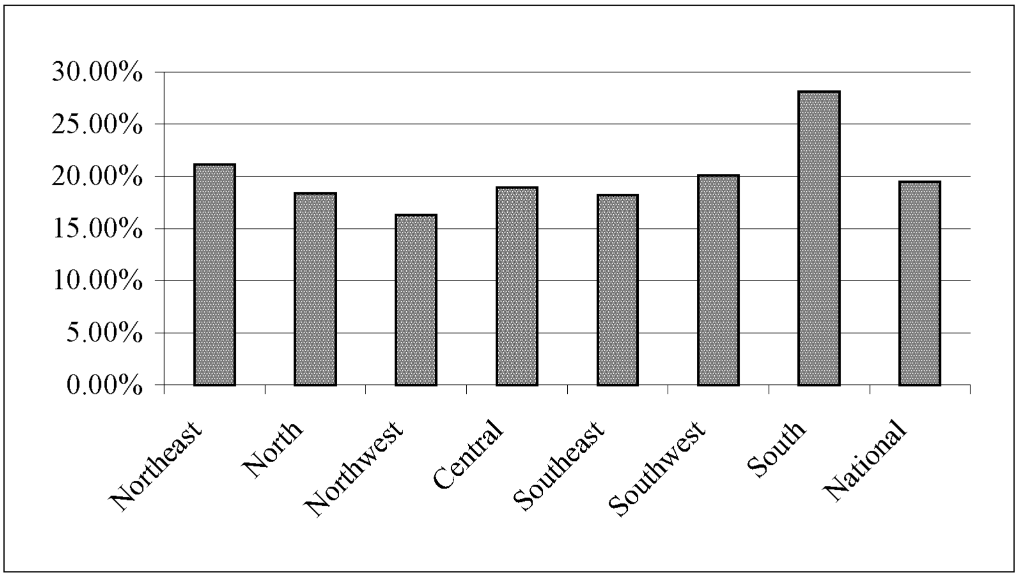

Figure 4-1: Contribution of Public Research Expenditure to GVAO Growth in China 1965-93

Source: Fan and Pardey 1995

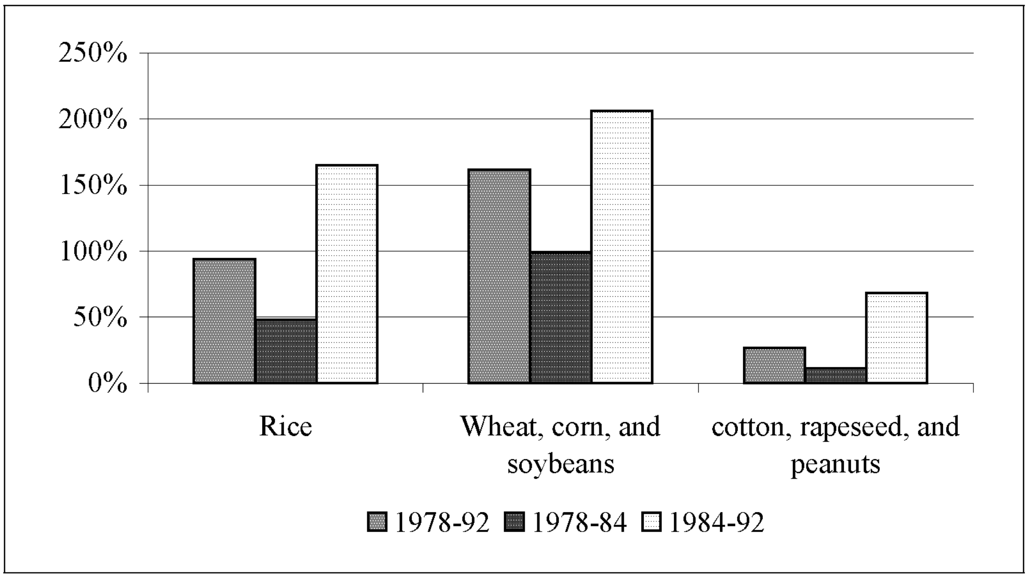

Figure 4-2: Contribution of Agricultural Research Expenditure to Crop Production Growth in China 1978-92

Source: Huang J. et al. 1997

This tendency is confirmed by a more recent study by Huang J. et al. (1997)[6] who suggest that far-reaching technological changes are attributable to the growth in Chinese research investments.

From this point of view, between 1978 and 1993 technology stock[7] emerged as the most important source of growth in rice production (94%) and as an even more significant factor in the expansion of production of other grains (wheat, corn and soybeans). Had all other factors remained constant, technology would have rendered output growth for other grains 60 percent higher than the actual growth rate. It is clear that the technological breakthroughs documented by Stone (1993) have been a driving force behind the expansion of China's grain production capacity. On the other hand, while technology's contribution to the production of other cash crops (cotton, rapeseed and peanuts) is considerable, the research system still exhibits a clear pro-grain bias. After 1984, China's agricultural growth was largely attributable to the nation's agricultural research stock (Huang J. et al. 1997).

Huang J. and Rozelle (1995a)[8] used a time trend variable to account for the effect of technological progress on grain. This revealed that it generated almost 77 percent of total yield increases registered between 1975 and 1990.

d. Commercialization of the Public Research System

Up until the early 1990s, there were very few incentives for scientists to work efficiently as agricultural research institutes were dependent on government funding. The government research structure led to misapplication of these funds by duplicating research institutes and projects (Ruifa et al. 1996) and employing high numbers of poorly educated staff (Fan and Pardey 1995). As the research institutes were under no direct financial pressure, they were able to release new varieties free of charge to seed companies. From the mid-1980s, research institutes were officially allowed to engage in commercial activities. However, since adequate government funds were still available, there was little pressure to embark upon such activities (Pray 1996).

In the early 1990s, funds were slashed due to inflation and budget restrictions. This forced research institutions to engage in profitable business activities. By

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6 Huang J. et al. (1997) analyzed provincial data from 1978-92 for sources of growth for the production of rice, other grains (wheat, corn, soybeans) and cash crops (cotton, rapeseed, peanuts). By applying a dynamic multisector model, they studied prices and quantities of output, labor, land, fertilizer, mechanical power, expenditure on research and irrigation, institutional change and environmental factors such salinity, erosion and precipitation.

7 Calculated from past public spending on agricultural research.

8 Huang J. and Rozelle (1995a) analyzed the source of growth of grain yield between 1975-90, setting the provincial grain output in relation to the use of chemical fertilizer, labor and irrigation, soil erosion area, salinized area, multiple cropping, natural disasters, technical progress and the effects of reforms in the early 1980s.

1994, it was not unusual for as much as 50 percent of a research institute's income to be generated by commercial activities such as guest houses, restaurants, trucking, cattle feed business, analysis for commercial non-agricultural firms, floriculture and poultry hatcheries. At the same time, research output dwindled. Institutes which could not find new income sources lost many of their scientists to higher paying jobs in more successful commercial operations (Pray et al. 1996).

In order to capitalize directly on their research activities, the institutes started to charge seed companies for the new varieties they developed. However, since they were not allowed to produce commercial hybrid rice and maize seed (the most profitable sector of all), they were obliged to sell inbred lines to the seed companies which, in time, developed the capability to produce their own inbred lines and stopped paying royalties. Although intellectual property rights existed officially, they were hardly enforced. In response, some research institutes established their own seed companies, or entered joint ventures with existing ones. However, it is still forbidden for research institutes and universities to sell hybrid rice and hybrid maize seed. They are only allowed to sell breeders and foundation seeds, not commercial seeds. This discourages both Chinese research institutes and foreign companies from investing in breeding new varieties. Finally, higher charges demanded by research institutes for new varieties and more stringent intellectual property rights have combined to encourage some seed companies to invest in their own breeding facilities (Pray et al. 1996).

The Chinese patents act was passed in 1984 and revised in 1992. It protects methods of producing new plants and genetic engineering processes, but it does not protect plant varieties or parts of plants. An act to protect plant breeders' rights is under consideration but has not been approved to date. Enforcement of patent rights or copyrights appears to be difficult for Chinese patent holders and virtually impossible for foreign firms. In spite of the problem of enforcement, there is an increase in the use of patents in agriculture (Pray et al. 1996).

4.2 Research Issues

a. Overview

The Chinese agricultural research system was traditionally one of the best in the developing world with a long history of development in seed breeding, water control, land preparation and technologies associated with the use of fertilizer (Carter et al. 1996).

Substantial technological advances have been achieved in grain production (Carter et al. 1996). In this context, the research system has successfully produced a steady flow of new varieties and other technologies ever since the 1950s (Stone 1988). Even today, agricultural research is, to a large extent, still crop related. In 1993, about half of both the personnel and expenditure in the research sector were devoted to crop production. Roughly 7 percent of the research personnel worked on fisheries issues, 12 percent on forestry, and these accounted for about 27 percent of the value of agricultural output. Only 8 percent were involved in livestock production issues (SSTC 1994).

Much of the work carried out by China's research system was devoted to the development of higher yielding varieties and the breeding of shorter season, photosensitive varieties to facilitate more intensive land cultivation (Huang J. and Rozelle, 1996). In mid-1970's, Chinese scientists were already able to increase rice yields significantly by the introduction of hybrid rice (Lin 1991). Farmers used semi-dwarf varieties developed in China several years before the release of Green Revolution technology elsewhere (Huang J. et al. 1997). Chinese-bred corn, wheat and sweet potato technologies were comparable to the best in the world in the pre-reform era (Stone 1993).

There is evidence that the incomplete commercialization of the research system led to a slowdown of research output. The number of rice varieties produced appears to have sunk in the 1990s and the yield potential of new varieties is also leveling off. The yields farmers have obtained rom new hybrids are no higher than those achieved using older hybrids. Maize research had two highly productive periods, namely the late 1950s and 1960s, when U.S. double cross maize hybrids were introduced and the late 1960s and early 1970s which saw the development of single-cross, disease-resistant hybrids. Most of the popular maize hybrids of today date from that period. This suggests a very slow turnover of varieties and also indicates that the maize research system has not been very productive since then (Pray et al. 1996).

b. Hybrid Rice

The government's continuous efforts to modernize the nation's rice economy has led to considerable successes in rice research (Stone 1988). The first fertilizer-responsive, semi-dwarf rice varieties were developed and extended in the early 1960s, and as early as the mid-1970's Chinese scientists were able to increase rice yields significantly by introducing hybrid rice. Expansion in water control and chemical fertilizer manufacturing capacities complemented these technological breakthroughs (Huang J. and Rozelle 1996).

Initial research successes in the breeding of hybrid rice were achieved in the early 1970s and by 1976 China had already begun to extend F1 hybrid rice to producers (Yuan and Chen 1991). The initial potential of yield advantage over conventional high yielding varieties was 10 to 20 percent (He et al. 1984). In 1990, it ranged from 1.03 to 2.02, with a median value of 1.14 (Huang J. and Rozelle 1996). Elasticity calculations performed by Huang J. and Rozelle (1996)[9] for the period 1975 to 1990 showed that the adoption of hybrid rice had

9 Huang J. and Rozelle compared the influence of hybrid rice and double/single cropping technology with that of institutional change on the generation of higher rice yields. Cultivators are assumed to make two sets of technological decisions: Hybrid rice adoption

a positive effect on rice yield (10.1 %), while chemical fertilizer application also increased yields (6.7 %) and labor input contributed to a reduction(-8,7%).

By the early 1980s, over 98 percent of China's rice area was planted with improved varieties. The hybrid rice area increased rapidly from 12.6 percent of sown area in 1978 to 41.2 percent in 1990. However, these aggregate figures conceal the significant differences in rates of adoption between the provinces which ranged from 0.2 to 88 percent in 1990. The reasons behind these differing adoption rates can be explained by the induced innovation hypothesis (Griliches 1957): the commitment to research is higher in regions with a greater number of rice consumers. This leads to higher funding and, in turn, a larger number of research products become available to farmers resulting in higher adoption rates (Lin 1992a). Huang J. and Rozelle (1996) showed that while seed production had been a limiting factor to the spread of hybrid rice in the early years, enlarged seed production capacities have since facilitated the expansion of its production at a rate of 5 percent per annum (Huang J. and Rozelle 1996).

Over the years, there have only been marginal differences in the sales prices for hybrid rice and conventional varieties (He et al. 1984). The relative profitability of new varieties, therefore, depends solely on their yield advantages. From the beginning of the 1980s and, more markedly, since the early 1990s, consumers in the economically rich east coast provinces have developed a preference for conventional varieties. Obviously, this trend has a negative influence on the production of hybrid varieties in these regions (Huang J. and Rozelle 1996).

Although there is no discernible pattern in the differing amounts of labor[10] required for hybrid rice, it does demand relatively high chemical fertilizer application levels. In the late 1980s, hybrid rice producers in some provinces used up to 30 percent more chemical fertilizer per hectare than conventional rice producers (He et al. 1984; Rozelle 1991; Lin 1991). The spread of the Household Responsibility System in the early 1980s increased the costs of technology adoption.

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vators are assumed to make two sets of technological decisions: Hybrid rice adoption and double cropping adoption. Using a six-equation rice sector model, provincial-level technology adoption, yield and factor demand are econometrically estimated, based on data from China's 13 rice growing provinces for the period 1975-90. The considered variables are: proportion of hybrid rice area sown, proportion of double cropped rice area, rice yields per total area, labor per hectare, chemical fertilizer per hectare, organic fertilizer per hectare, total rice sown area previous year, hybrid/conventional yield difference, rural income per capita, time trend, HRS, cultivated area/rural population, average rice price, wages in rural area, price for chemical fertilizer, salinity and disaster.

10 While farmers expended significantly more labor on rice production in central Jiangsu province, Eastern China (Yea and Rozelle 1993, Rozelle 1991), Hunan farmers in Central China used less labor on hybrid rice (Lin 1992a, Lin 1994a). The nation-wide effect is that hybrid rice producers use less labor (Huang J. and Rozelle 1996).

Possible factor constraints at household level, such as liquidity shortage, slowed the spread of hybrid rice by 12 percent (Huang J. and Rozelle 1996).

Table 4-2: Hybrid Rice and Double Cropping in China: Yield Differences and Applied Area

	Yield Difference	% of rice area
Hybrid Rice 1990		
South	19%[a]	49%
East	7%[a]	24%
Central	22%[a]	40%
Southwest	55%[a]	59%
Double Cropping[b]		
1975	59%	71%
1980	66%	66%
1985	64%	60%
1990	63%	58%

[a]Average of provincial averages 1988-90
[b]Total national

Source: calculated from Huang J. and Rozelle 1996

c. Double Cropping

In order to enhance the yields obtained from the arable land available, production was maximized by increasing the number of crops harvested per unit of cultivated land (Carter et al. 1996). To meet this target, researchers developed rice varieties that allowed a switch from one to two rice crops per year. The maturation time was reduced, cold tolerance enhanced and crops were rendered photoperiod insensitive. This new technology can be combined with hybrid rice technology in that hybrid rice can be sown in one of the two seasons in a double-cropping rotation (Huang J. and Rozelle 1996).

In 1975, the annual per hectare yield of double cropped rice exceeded that of single-season rice by 56 percent (see Table 4-2) and this difference rose to 63 percent in 1990. This significant yield difference encouraged agricultural leaders to push the level of double cropping up to 71 percent in 1975. Nevertheless, the high yield gains achieved with double cropping are obtained at the expense of increases in labor and fertilizer application.[11] When opportunity costs for labor rose during the mid-1980s, two-season rice became economically inefficient in regions with high wage levels. Consequently, farmers in the coastal provinces switched to single-cropping as this led to a marked decline in the labor devoted to agriculture and agricultural profits increased[12] accordingly. However, market delivery obligations for rice compelled producers to expand their sown area. The adoption of two-season rice technology meant that it was possible to avoid substituting other crops with rice. In spite of the efforts of local government to enforce an increase in production, the area planted with two-season varieties dwindled on average from 66 percent in 1980 to 58 percent in 1990, whereby this decline was even more significant in the highly developed provinces of Jiangsu and Shanghai (Huang J. and Rozelle 1996).[13]

d. Contribution of Agricultural Research to Agricultural Growth

Huang J. and Rozelle (1996)[14] calculated that the adoption of hybrid rice varieties between 1975 and 90 was a major source of rice yield increase, accounting for 56 percent of total growth during that period. This contribution amounted to 70 kg /ha per year between 1978 and 1984. Thanks to a steady annual increase of 75 kg/ha between 1985 and 1990, it was the primary source of growth at that time and helped offset the downward yield trend caused by environmental problems and rising input prices as compared to output prices. The adoption of double cropping made a 14 percent contribution to total rice yield increase between 1975 and 1990, whereby this positive effect occurred mainly pre-1984. Later, double-cropping was less profitable due to rising wages and fertilizer prices (Huang J. and Rozelle 1996).[15]

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[11] During the 1980s, in Fujian province and in 1985 in Sichuan province, the labor and fertilizer used on two-season rice was more than double the levels for single-season rice. Throughout China, double cropping adoption between 1975 and 1990 led, on average, to a 12 percent increase in labor and a 79 percent increase in fertilizer per hectare sown (Huang J. and Rozelle 1996).

[12] Huang J. and Rozelle (1996) showed that as wages doubled, the area sown with two-season rice dropped by 9 percent.

[13] In Jiangsu province, double cropping rice area dwindled from 47 to 2 percent and in Shanghai from 97 to 19 percent.

[14] see footnote 9 page 89

[15] Double cropping has a high elasticity of fertilizer and labor (0,78 and 0,12).

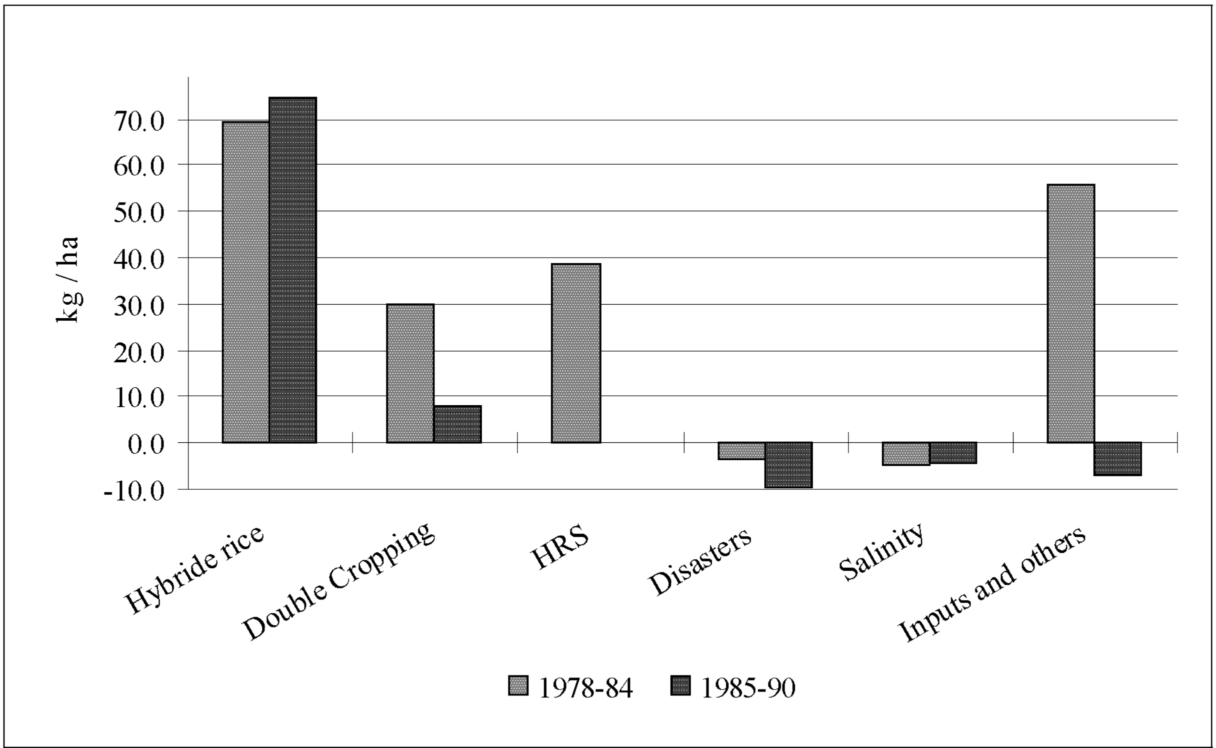

Figure 4-3: Accounting for Annual Yield Growth in Chinese Rice Production 1978-90

Source: Huang J. and Rozelle 1996

4.3 Seed Companies

a. The Old System

Prior to 1992, the Chinese seed industry was organized within a hierarchy of different official administrative levels including 2200 county, 500 prefecture, 27 provincial, 3 metropolitan seed companies and the National China Seed Corporation (NCSC). County seed companies organized the production of most commercial seed through contract growers; prefecture seed companies supplied them with foundation seed, and they also produced commercial seed. The provincial seed companies and NCSC were primarily planning bodies and were responsible for all inter-provincial trade, and the NCSC also controlled all imports and exports of seed. In addition, 2'500 township seed supply stations distributed seed to farmers and organized the production of non-hybrid seed. Under the coordination of the national seed plan, seed companies received new seed varieties from the research institutes free of charge and orientated their production and supply according to its stipulations (Pray et al. 1996).

b. Incomplete Reforms

The national seed plan was abolished in 1992 and seed companies at all levels were instructed to operate as commercial enterprises. At the same time, government subsidies were cut. Although the service producers' need for an efficient seed system was greater than ever, the existence of two opposing forces meant that the commercialization process in this field proceeded more slowly than in almost any other sector of the agricultural economy: there were those in favor of rapid decontrol while others demanded that the seed industry should remain under strict management of the political leadership (Huang J. et al. 1997a). The forces that had supported reforms in the grain, fertilizer and other branches of agriculture since the late 1980s also advocated the liberalization of the seed industry. The national government drafted ambitious plans to provide better incentives for seed industry officials, reduce price controls and eliminate unnecessary regulations (FAO 1995). On the other hand, provincial leaders are still called upon to assume the responsibility for grain self-sufficiency in their provinces. and they fear they will lose control of grain production if seed supply is governed entirely by market forces (Huang J. et al. 1997a).

Prior to 1992, new seed varieties were tested jointly by research institutions and seed administration stations which were divisions of the county seed companies. With the commercialization of seed companies, service functions such as seed inspection, seed certification and variety testing were detached from their commercial seed operations. In some places, the newly established seed stations were felt to be biased when called upon to assess the seed quality of the company to which they once belonged. This led to the appearance of substandard seed on the market.

Farmers and seed companies used to receive substantial subsidies for growing processing seed. These subsidies were cut considerably in the early 1990s although some were still in force in 1994: basic salaries to seed companies for quality control services and subsidies to farmers for seed production, low interest government credits and government support or write-off loans to companies running at a loss. Seed companies are not allowed to go bankrupt or to stop producing seeds (Pray et al. 1996).

4.4 Price and Marketing Policy

Before 1993, central government issued general guidelines on seed pricing and the provincial price bureaus fixed the seed prices for their provinces. In spite of the fact that the companies are now allowed to set prices themselves, the government still has the right to intervene if the prices exceed a certain "seed price to grain price" ratio[16] or profit margin[17]. In some provinces the provincial price

[16] 1.5x - 2x for regular seed, such as wheat and soybeans, 3x for hybrid maize and 6 x for hybrid rice.

bureau still fixes seed prices. As a result, seed prices are low: they changed little, for example, between 1988 and 1995.[18] These low prices depress margins, making it almost impossible for seed companies to invest in R&D, pay for technology developed by public research institutes or foreign firms or invest in maintaining and improving their equipment or physical facilities. Many companies cannot even cover their variable costs of production and are bailed out by the government every year. The seed industry is not an attractive business and there are few opportunities for foreign companies with technology and management skills to make worthwhile returns.

Other market actors, such as collective, private and government institutions are now allowed to enter the market for vegetable, fruit and flower seeds and non-hybrid seed for all other food crops. However, they must apply to the local government for a commercial license before they can begin their sales operations. Government seed companies still hold exclusive production and distribution rights for hybrid seed varieties. The official rationale behind this policy is to ensure that high quality hybrid seed is available to farmers. In 1995, this led to a situation whereby, in most counties, only state and county seed companies distributed hybrid seeds. As a result, seed marketing for the major field crops is still dominated by government seed companies. For example, in 1995 about 80 percent of the maize, rice and wheat seed supplied to farmers in Zhejiang and Shandong provinces[19] was purchased from government seed organizations i.e. county seed companies and agricultural technical stations. In the case of the vegetable seed market, almost two thirds of the supply was sold through free markets, making it the only sector in which non-state enterprises held an significant market share. However, the importance of free market channels in the vegetable sector is not attributable to recent reforms but rather to the fact that the vegetable seed market has always been less subject to restrictions. Consequently, the policy changes which took place in the early 1990s do not seem to have generated any appreciable increase in the market share held by private and other enterprises.

Today, local governments are still in a position to restrict seed trade between counties and provinces. As a result, the seed trade as a whole presents a somewhat varied picture. Many counties and provinces prohibit the sale of seed by state owned seed companies from other counties and provinces, unless it is transacted through the local county or provincial seed company. Some only permit trading in vegetable seeds, while in other provinces there are no restrictions on sales.

Prior to 1993, the China National Seed Company had a monopoly on seed imports. After this date, provincial seed companies and some county seed com-

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[17] Profit margin of seed companies is not allowed to exceed 10 to 20 percent.

[18] Survey in Zhejiang and Shandong provinces in 1988 and 1995.

[19] See footnote 18

panies also started importing seed from abroad, although so far these have mainly involved vegetable seed. Private and foreign firms are still not allowed to import seed directly and are obliged to do so through government seed companies.

The original idea behind the Chinese seed system was to ensure a rapid transfer of technology from research stations to farms and to supply farmers with some of the least costly seed in the world. Nevertheless, today the quality of seed for certain crops is inferior, farmers use an excessive amount of seed and do not have access to some of the latest technology from abroad. Current government policy in the seed sector involves limited reform and policies which have reduced competition and opened up the possibility for local monopolies when controls on seed prices are relaxed. The effect of restricting access by collective and private companies to the vegetable sector has been to keep the most efficient part of the Chinese economy out of the most profitable branch of the seed industry (Pray et al. 1996).

Observers have called the seed industry one of the major constraints to the spread of technology. It discourages investment in the creation and extension of new crop varieties and constitutes a potential barrier to the nation's campaign to achieve the ambitious supply goals it has set itself for the future (World Bank 1996). Further commercialization could encourage the development and introduction of better cultivars for many major crops (Pray et al. 1996). Low seed prices, weak intellectual property rights and restrictive regulations have combined to keep foreign seed companies out of China which means that the country has no access to the latest technologies in genetics and seed production and processing. Many Chinese scientists agree that the introduction of new varieties could generate considerable potential for increasing the yields of most crops (Pray et al. 1996).

4.5 Agricultural Biotechnology

a. Research Activities

In 1986, the Chinese government initiated the National Technology Plan which designated biotechnology a national priority, with the greatest emphasis placed on agriculture (BIO 1995). Over the last fifteen years, rapid research developments have been achieved in the fields of biotechnology and molecular biology. Scientific infrastructure was set up at several National Key Laboratories as well as at a number of smaller laboratories equipped with modern facilities. During the same period, funding was extended and major research programs supported at national level[20] as well as by local governments which also gave agricultural biotechnology top priority (Zhang Q. 1999). In the early 1990s, central govern-

[20] National Program of High Technology Development (863 Program) and National Program of the Development of Basic Research (973 Program)

ment spent an estimated 30 mil $ annually on biotechnological research (BIO 1995). The biotech research budget in 2000 amounted to 361 mil. $ as against 120 mil. $ in 1999 (Holland 2000).

Today, there are more than a dozen domestic institutions engaged in agricultural biotechnology research (Holland 2000). These include traditional agricultural research institutions such as the Chinese Academy of Agricultural Science (CAAS), provincial academies of agricultural science and agricultural universities, as well as general universities and some institutes of the Chinese Academy of Science (CAS) (Pray 1999).

These institutions handle basic research, as well as applied research aimed at the development of commercial transgenic crop varieties. Basic research focusses on genome studies in rice and other cereals and the development of molecular cloning of a large number of agriculturally useful genes. Applied research aims to develop disease and insect resistant crops[21], increase tolerance to stress such as drought, soil acidity and salinity[22], improve product quality[23] and enhance yield potential[24] (Zhang Q. 1999). Transformation technologies have become firmly established for most crop species including major cereals such as corn, rice and wheat and most other important crops such as cotton, tomatoes, potatoes, soybean, rapeseed, peanuts and cabbages. In 1998, field testing and commercial production started with rice, wheat, corn, cotton, tomatoes, peppers, potatoes, cucumbers, papayas and tobacco (Zhang Q. 1999).

Researchers from Beijing University have developed tobacco plants that absorb cadmium accumulated in the soil. This technology may well help to decontaminate cadmium polluted farmlands (BIO 1995). Chinese scientists have been trying to crack the genetic code of rice since the early 1980s. The China National Rice Research Institute has been awarded a commercial license to sell herbicide resistant rice in Zhejiang province (Holland 2000). Field tests of the Swiss development, the so-called "golden rice", with added vitamin A, are already under way in the central city of Wuhan (Holland 2000).

Private firms involved in agricultural biotechnology research and the commercialization of new technology are almost exclusively foreign companies (Pray 1999). Foreign seed companies and agricultural chemical companies first entered the Chinese market with conventional products. Initially, that is to say in

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21 Extensive application of agricultural chemicals has created a vicious circle, in which these excesses have led to rapid deterioration of the environment, thus rendering crop production even more dependent on the application of chemicals.

22 In North West China, water supply is a major obstacle to crop production, in South and Central China soil acidity is the limiting factor and salinity occurs in large areas of the East coastal region.

23 High yielding rice cultivars and hybrids have poorer cooking and eating qualities. Thus, they are not appreciated by producers and consumers.

24 In the 1990s, the growth in yield potential of new cultivars slowed in spite of the large number of new cultivars released over the last decades.

the late 1980s and early 1990s, it was customary for foreign seed firms to start off by collaborating with public research institutes, e.g. Pioneer and the Cereal Breeding Institute at CAAS ran joint maize trials, Delta and Pine Land and the Cotton Research Institute of CAAS collaborated on a research program and Pacific Seeds (Avanda) worked with the provincial academy of agricultural sciences in Wuhan and the Australian government on a joint rapeseed and canola program. Although none of these efforts led to the release of commercial varieties, foreign companies continue to carry out contract research and varietal testing together with public sector research institutes.

In 1998, Monsanto was the only private company to be engaged in research activities in the domain of agricultural biotechnology. The company's activities involved the launch of corn and soybean projects and a joint venture concerning cotton. Monsanto proposed the setting up of a joint CAAS - Monsanto rice biotechnology research institute. However, CAAS could not raise the necessary capital and there were unresolved uncertainties regarding intellectual property rights (Pray 1999). After Monsanto had decided to make the rice genome sequence public, with a view to encouraging research into GM crops in the developing world, it announced in April 2000 that these findings would also be shared with Chinese scientists. In this way, China will be able to save up to 15 years of research effort (Holland 2000)

b. Commercialization of GM Seed in China

As it is prohibited for research institutes to produce commercial seed themselves, the successful commercial introduction of new GM seed in recent years has always been based on a joint venture between a research institute and an existing state seed company. This not only applied to foreign seed companies seeking access to the Chinese seed market via this channel, but also to public research institutes that had succeeded in developing new varieties. Within the state sector, agricultural research institutes are developing commercial enterprises, albeit state-owned ones, or are joining up with existing state seed companies.

The first public commercial collaboration in biotechnology involved the University of Beijing and the government tobacco companies and led to the commercialization of transgenic tobacco. The university laboratories transformed standard tobacco into virus and pest resistant varieties, while government tobacco companies distributed seed to their growers. The LaiZhou Academy of Agricultural Sciences (prefecture level) set up a commercial hybrid seed firm in Shandong together with two county seed companies. Other research institutes have set up their own seed firms with a view to commercialization, but have been hindered by regulations and lack of capital.

In the mid 1990s, an increasing number of foreign firms sought to enter the Chinese seed business by embarking on joint ventures with provincial seed companies, the China National Seed Industry Group, or provincial seed testing stations (Pray 1999).

The first successful commercial introduction of modern GM seed from a multinational company involved Monsanto's "Bollgard Bt" cotton in 1998 and was the result of a joint venture between Monsanto, Delta and Pine Land and the Hebei Ji Dai Cotton Seed Technology Company Ltd. (Pray 1999). The "Bollgard Bt" cotton seeds were imported from the U.S. and genetically improved by Ji Dai Co (BGU 1.1.1999). The Department of Agriculture finally granted Ji Dai Co. approval for commercialization in Hebei province (BGU 1.1.1999). It was planted commercially for the first time in 1998 on about 80'000 hectares. In 1999, 90 percent of cotton farmers in northern Hebei were sowing Bt cotton (Pollock 2000). Monsanto now accounts for 2 percent of China's cotton seed market (Pray 1999). In spite of poor protection of intellectual property, inefficient distribution methods and multiple layers of bureaucracy that have depressed profits, the company plans also to introduce GM corn in China (Holland 2000).

Other companies such as DeKalb, Cargill and Chani Tai (Charoan Pokphand) are all using joint ventures to enter the conventional seed industry. Pioneer has set up a 100 percent owned research company, but will have to join up with a government seed company to commercialize its products. The Hunan Hybrid Rice Research Center established a joint venture with the U.S. firm Ticetec in the late 1980s to develop markets for hybrid rice in the Americas. This joint venture is now starting to develop Chinese markets (Pray 1999).

c. Approval and Release

Prior to 1996, there were no special regulations or application process for the release of GM crops. Field trials were conducted and managed by each research institution and new genetically engineered varieties were released through the regular varietal release channels (Pray 1999). This made China attractive for multinational firms looking for somewhere to conduct field tests (Raguth 1999).

Before 1996, field trials were conducted for wheat, rice, soybeans, cotton, corn, tobacco, potatoes, tomatoes, sweet peppers, papayas, cabbages and alfalfa. Transgenic varieties of tobacco and tomato were already grown commercially. The virus resistant tobacco released in 1989 was the first genetically engineered crop in the world to be grown commercially (Pray 1999). In 1996, virus resistant tomatoes were grown on 20'000 hectares and tobacco on 800'000 hectares (Hemmer 1997).

After 1996, trials and the commercial release of transgenic plants had to be approved by a national biosafety committee. According to Chinese scientists,[25] these tests fulfill the standards of the US Food and Drug Administration and the

[25] Zhang-Liang Chen, Vice President of Peking University and director of the National Laboratory of Protein Engineering and Plant Genetic Engineering

national Biosafety Committee, thus ensuring GM does not have any side effects (Pongvutitham 1999).

The majority of the 35 field trials approved in 1997 were carried out by institutes of the CAS, Beijing University and the CAAS. Monsanto was the only private international company that was granted approval for field trials or commercial use. None of the provincial academies of science, which boast the largest number of scientists, submitted any applications for trials or commercialization. The field trials involved five major field crops (rice, maize, soybean, cotton and tobacco) and five horticultural crops (tomatoes, potatoes, green pepper, chili pepper and a tropical fruit).

As of June 1998, six transgenic varieties have been approved for commercial production. These include the Monsanto joint venture's Bt cotton in Hebei province, the Chinese Academy of Agricultural Science's Bt cotton, Beijing University's virus resistant tomatoes, sweet pepper and petunia, Huanzhong Agricultural University's delayed ripening tomato. The transgenic tobacco varieties, which have been in the field for many years, were not approved.

The Chinese Approval system for GM crops has been criticized as being vulnerable to political and economic pressure, especially as regulators now also have to earn part of their income from commercial activities. Decisions to approve or disapprove new plant varieties and transgenic plants are not transparent and seem to be arbitrary or biased, e. g. it has been reported that in the case of Monsanto's Bt cotton the political leverage exercised by the Vice-governor of Hebei province played an important role in getting the genetically engineered varieties through the regulatory obstacles and into the field (Pray 1999).

In China, the use of GM seed is growing rapidly, although the USA has taken the lead in terms of volumes (Holland 2000). Chinese scientists and officials are slowly becoming aware of their biosafety responsibilities and have reacted by introducing compulsory registration before a GM crop can be released. However, there is very little opposition to genetically modified crops, no matter whether in rural nor urban areas (Holland 2000). The world-wide debate on genetic modification has left China unaffected (Pollock 2000). This, coupled with the ongoing research activities, means that a very rapid increase in the area planted with transgenic crops can be expected over the next few years (Zhang Q. 1999).

d. Constraints

There are three factors that may hinder large scale adoption of crops developed using biotechnology: opaque approval system, intellectual property rights and the seed distribution system.

At present, private firms are reluctant to work with public scientists and state seed companies for fear they will lose control of their proprietary technology. Government research institutes are apprehensive of concluding contracts with state seed companies for the sale of new plant varieties because in the past they have not received the royalties due to them. The net result is that research institutes prefer to set up their own seed firms rather than collaborate. Stronger intellectual property rights, including plant patents and enforcement of existing legislation on plant breeders' rights could help to increase collaboration (Pray 1999). However, in 1999 many scientists still chose to ignore the existence of intellectual properties. One reason for this that must be mentioned is the shortage of intellectual property experts in China. At the same time, Chinese scientists frequently fail to recognize and honor intellectual property rights (Zhang Q. 1999). Almost all transgenic crops that have been developed to date in China involve unclarified intellectual property rights.

At present, state-owned seed companies are the only enterprises allowed to sell seeds for the major field crops and 80 percent of pesticide sales are also restricted to Chinese firms (Pray 1999). The reforms of the formal network system which were implemented in the 1990s with a view to dispersing agricultural technology and seed are making very slow headway. The result is a situation in which the old institutions are gradually changing and abandoning their former activities, while an efficient private seed sector has not yet become firmly established (Zhang Q. 1999).

Summary

Public Research Institutions

The Chinese government's overall goal is to increase agricultural production. The development of improved seed has therefore been given high priority ever since the early 1960s. Sustained investments in public research have led to the development of one of the world's largest agricultural research systems operating at government, provincial and county level. However, the large number of 62'800 scientists employed in 1993 conceals the fact that only 5 to 6 percent hold a higher academic degree. The available evidence indicates that one quarter of the agricultural output growth between 1965 and 1978 can be attributed to agricultural research. This contribution to growth declined somewhat between 1979 and 1993. On the other hand, a more crop specific approach revealed that, in the case of all major crops, the level of research stock was the major source of agricultural growth throughout the late 1980s and early 1990s. This supports the idea that agricultural technology was adopted to a far higher degree after families were released from the communal production system. All in all, the impact of research was higher in South China than in the rest of the country.

In the early 1990s, funds for research institutes were cut back so drastically that they were compelled to engage in commercial activities. They found it difficult to generate incomes by selling their newly developed varieties since intellectual property rights were weak and they were not allowed to produce and sell hybrid seed themselves. The seed companies, in turn, were also forced to become profitable. Consequently, they were unwilling and, in some cases, unable to pay royalties over a longer period. Although there have been attempts to stiffen the patent law, it is still hard to enforce.

As a result, research institutions diverted a considerable part of their efforts towards other commercial activities such as guest housing, restaurants, transport business, floriculture, etc. In 1994, half of their incomes were generated this way.

Research Issues

A large amount of agricultural research is crop related and focusses on the development of higher yielding varieties and varieties that grow in shorter periods thus allowing more than one harvest per year. The Chinese research system was very successful in the 1970s, developing rice, wheat, corn and sweet potatoes that were among best varieties in the world at that time. Up until recently, they produced a steady flow of new varieties. However, incomplete commercialization and cutbacks in government support led to a slowdown in research output in the 1990s.

The adoption of hybrid rice was actively promoted by the government and rose from 13 percent in 1978 to 41 percent in 1990. Urban markets are liberalized, which means that consumers can express their preference for traditional varieties. Since the price of hybrid rice is lower than for traditional varieties, adoption is stagnating.

The development of fast growing varieties facilitated a switch from one to two harvests per year with a potential yield increase of approximately 60 percent. Although this production mode is much more labor and fertilizer intensive, the government pushed double cropping up to 71 percent of the total area under rice in 1975. However, rising opportunity costs for labor from the mid-1980s made double cropping increasingly unattractive in provinces with strong industrial development. In spite of the government's efforts to increase rice production, the double cropping area had declined to 58 percent by 1990.

Seed Propagation and Marketing

Up until 1992, the Chinese seed industry operated predominantly according to the national seed plan. Seed propagation was managed by a hierarchical system of 2200 county, 500 prefectural and 27 provincial seed companies, which received newly developed seed free of charge from the research institutes and sold it to Township Seed Stations at planned prices and quantities. The whole system was subsidized by the government.

1992 saw the abolition of the national seed plan and the companies were instructed to operate as commercial enterprises. Other market actors were able to enter the seed market for vegetables, fruit, flowers and non-hybrid varieties of all other food crops. The production and marketing of hybrid seed is restricted to government seed companies. The government can still dictate price levels and profit margins. Frequently, these prices are so low that seed companies cannot afford to maintain or improve their equipment, buy new varieties and, in some cases, they cannot even cover their variable costs. As seed companies are not allowed to go bankrupt, they continue to receive government subsidies.

In the mid-1990s, provincial governors assumed the responsibility for provincial grain supplies, forcing seed companies to produce according to perceived provincial seed requirements rather than according to profit maximization. Provincial governors are also in a position to inhibit inter-provincial trade, which has led to a disparate situation in which seed markets are extremely restrictive in some provinces and rather liberal in others.

Agricultural Biotechnology

Over the past few years, Chinese government expenditure on biotechnology research has increased significantly from 30 mil. $ in 1990 to 361 mil. $ in 2000. Today, over a dozen institutions are engaged in agricultural biotechnology research, both basic and applied. Transformation technologies have been firmly established in all major crops and some crops are already being produced on a commercial basis.

In the late 1980s and early 1990s, foreign seed companies such as Pioneer, Pacific Seeds and Delta and Pine Land started to collaborate with public research institutes, all, however, in the conventional breeding sector. In 1998, Monsanto was the first foreign company to launch biotechnology research projects in China.

As the production and commercialization of seed is restricted, any introduction of new GM seed in recent years has been the result of a joint venture between a research institute and an existing state seed company. These consist of Chinese research institutions as well as several multinational companies.

In 1989, China was the first country where genetically modified crops were cultivated on a commercial basis. However, there was no law stipulating that GM crops must treated differently from other new seed varieties. An approval system for field trials and commercialization of GM seed was introduced in 1996, but this system has been criticized as being biased. Although several new varieties have been introduced successfully, large scale adoption is inhibited by weak intellectual property rights, market access restrictions and the inefficient seed distribution system.

5 Pesticides Sector

This chapter provides an overview of the Chinese pesticides sector. The first section outlines the manufacture of pesticides and the types produced as well as reviewing the industry's development, research system, structure, current adjustments and foreign direct investments. The second part deals with the market level including pesticide registration, intellectual property rights, domestic market channels and the foreign trade regime. The final section discusses the situation at farm level, focussing on factors affecting the demand for pesticides, today and in the future.

5.1 Chinese Pesticides Industry

a. Pesticides Output

There was no pesticides industry prior to the founding of the People's Republic of China. Since that time, pesticide output has risen continually reaching an output of 395'000 tons in 1997. Today, China is the world's second largest pesticide producer, surpassed only by the US (Shubao 1999).

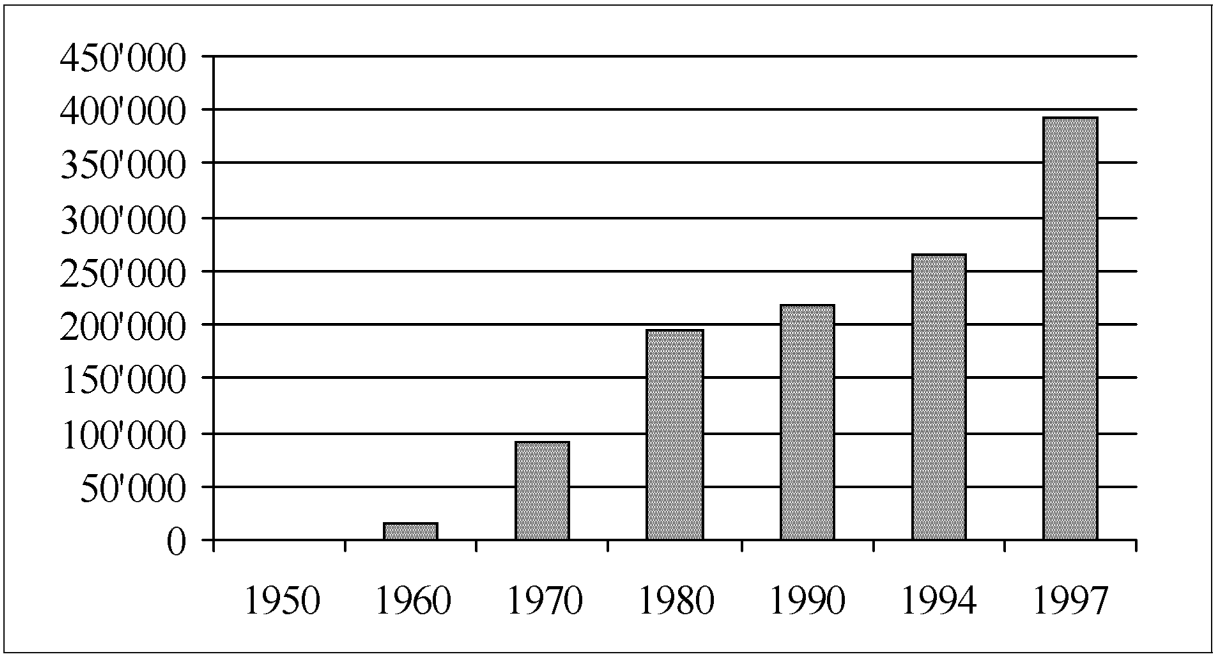

Figure 5-1: Production of Pesticides 1950-1997

Source: Cheng 1990 and Shubao 1999

There has been a steady increase in the output of all pesticides. However, the share held by insecticides declined gradually from the early 1980s onwards, while that of herbicides grew. In 1997, insecticides still accounted for 69 percent of production, fungicides for 10 percent and herbicides 17 percent (Shubao 1999).

Table 5-1: Total Pesticides Output by Type 1985-1997

'000 tons	Total	Insecticides	Fungicides	Herbicides	Growth Reg.
1985[1]	205	159.4	26.2	17.9	1.6
1991[2]	253	196.1	35.0	19.8	2.5
1997[2]	395	274.5	41.8	67.4	10.8

Source: Cheng 1990[1], Shubao 1999[2]

b. Development of Chinese Pesticides Industry

Generally speaking, the development of the Chinese pesticides industry can be divided into four phases: 1. initial establishment (1950-1960); 2. consolidation of development (1960-83); 3. production structure adjustment (since 1983) and 4. development of types with new generation molecular structures (since1995).

Pesticides derived from minerals and plants have been used in China for a long time, but only in small amounts. Production of synthetic organic chemicals started in 1942 with small quantities of DDT for social hygiene requirements. However, production stopped after a short time. In 1949, there were a very small number of facilities throughout the country producing commercial white arsenic, calcium arsenate, lead arsenate, copper sulphate and rotenone, their output amounting to not more than a few dozen tons. A plant for DDT and 666 production went into operation in 1951 and numerous plants of this nature were built in subsequent years (Dunli 1991).

The use of chemical pesticides in agriculture rose following the introduction of People's Communes since their application was cheaper, more efficient and more convenient than traditional crop protection measures (Chenxiang 1988). In the 1960s and 1970s, a group of key pesticide factories was completed and new types were introduced (Shubao 1999). Three years of severe famine between 1959 and 1961 moved Chinese agricultural policy-makers to embark on an aggressive Green Revolution strategy that included the introduction of chemical pesticides (Stavis 1974).

BHC became the principal insecticide in the 1960s and 1970s due to its simple manufacturing process, cheap materials, effective, broad spectrum pest control and low acute toxicity to mammals. By the end of the 1970s, annual production exceeded 100'000 tons of technical BHC.

During the late 1950s and the 1960s, pesticide research focused on organophosphorus insecticides (Cheng 1990). Construction of the first organophosphorus insecticide plant commenced in 1956 and it was commissioned the following year. This was followed by a gradual increase in the number of plants manufacturing organophosphorus insecticides (Dunli 1991). Their widespread application was adopted parallel to the introduction of semi-dwarf rice varieties (Shubao 1999).

Organophosphates were first introduced in the 1970s and became the most important insecticide in the 1980s. Dithiocarbamate fungicides were developed and commercialized in the early 1960s (Cheng 1990).

In April 1984, the government officially prohibited the manufacture, sale and use of BHC and DDT after which these well-known insecticides disappeared from the Chinese pesticides market. Later, the production of DBCP, chlordimeform, fluoracetamide and nitrofen was also abandoned.

While pesticide research in the 1960s and 1970s concentrated mainly on insecticides and fungicides, research on herbicides got under way in the early 1980s and has undergone considerable development in the meantime.[1] After 1980, pesticide research institutes and universities devoted more attention to pyrethroid insecticides and certain herbicides. At the same time, good results were also achieved with antibiotics and natural products (Cheng 1990). Several new, highly efficient types were introduced in the 1980s and quickly gained market shares. By the mid-1990s, there had been a significant increase in the total shares held by fungicides and herbicides (Shubao 1999).

In 1990, the Chinese pesticide research system was lagging some 15 to 20 years behind the status of developed countries. Since very few Chinese technicians make determined efforts to develop new pesticides, some of the products available are obsolete and no longer exist on the world market (CEIS 1998). On some occasions, China launched the production of new pesticide types, developed abroad, after the inventor's patent rights had expired (Cheng 1990).

In 1997, there were nearly 180 types and over 1000 preparations on the market. The output of 8 types[2] exceeded 10'000 tons and that of a further 5[3] amounted to over 5000 tons, whereby the output of organophosphorus insecticides still accounted for over 60 percent. The output of toxic insecticide alone surpassed 70'000 tons and accounted for over one quarter of total production (Shubao 1999).

Large quantities of toxic pesticides such as methamidophos are still being produced and applied, threatening the health of producers and consumers alike (Cheng 1990).

Rapid economic development in recent years has led to a change in awareness regarding the impact of pesticides on the environment and operational safety in the production and use of pesticides (Shubao 1999);

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1 The herbicides used in China in 1990 were phenoxyacetic acids and their esters, dyphenyl ester, ureas, organophosphorus compounds and carbamates.

2 Methamidophos, Sha Chong Shuan, Gyphosate, Dichlorvos, Trichlorfon, Methyl Parathion, Omethoate and Dimethoate.

3 Monocrotophos, Mancozeb, Butachlor, Cabendazim, and Acetochlor.

e.g. in 1998, Shanghai prohibited the use of methamidophos and also abolished VAT exemption for its production. Given that other regions of the world are about to replace highly toxic pesticides, Chinese farmers will soon find it difficult to export their goods if they continue to use these products. It follows that the Chinese pesticides industry is under pressure to accelerate product restructuring and must make a concentrated effort to develop suitable alternatives. Should it fail to do so, it will find itself in an extremely unfavorable position. If domestic research and development is unable to fulfill the requirements of the home pesticides industry, it will be in danger of losing substantial market shares to foreign companies (CCR 16/11/99).

Consequently, there is a trend towards production structure readjustment, namely:

- an increase in the share of types with high efficiency, low toxicity and safe handling;
- a reduction in the share of highly toxic varieties;
- an increase in the share of herbicides and fungicides;
- the development of new, environmentally compatible, low-pollution preparations (Shubao 1999).

c. Pesticides Research System

Until recently, pesticides research was the exclusive domain of public research institutions which forwarded their results to the industry. There are over a dozen pesticides research units (Shubao 1999a), some of which are controlled by central government, while others are answerable to the provincial authorities (Cheng 1990). Research and development funding comes from government research funds, research institute funds, income generating products and from companies in the chemical industry (US Embassy 1996).

Research is organized through institutes which are run by the Ministries of Chemical Industry, Agriculture, Health and Education and the Academy of Sciences with the participation of local research institutes (Cheng 1990). There are three major research units at national level: 1. the Shenyang Chemical Industry Research Institute under the Ministry of Chemical Industry; 2. the Elemental and Organic Chemistry Institute at Nankai University in Tianjin and 3. the Plant Protection Institute at the Chinese Academy of Agricultural Science. In addition, most provinces and many large chemicals companies run their own chemical research institutes (US Embassy 1996).

As all these research units are small scale, they lack formulation capability and can only imitate pesticides which have already become commodities in foreign countries. In response to intensified protection of intellectual property rights, the Chinese government has decided to set up two national research centers with formulation capability in Shenyang and at Nankai University.

There are a large number of pesticide plants in China, but few carry out research. They buy manufacturing technology for new pesticides from research institutes or co-operate with them by providing pilot plants and capital. Recently, pesticide producers have enlarged their input in scientific research and have gradually increased the funds spent on research and development. Some key pesticide producers have set up their own research and development units or joined up with specialized research units (Shubao 1999a).

d. Government Policy

Prior to the industrial reform of the mid-1980s, the government did not rate pesticide production as a major priority. Infrastructure was available for the cheap, efficient production of large quantities, which meant that it was not necessary for the government to exercise stringent production control as was the case in the fertilizer sector. When the Rural Communes were abolished, the emerging TVEs started to produce pesticides in small scale firms, using low-tech production methods (Rozelle 1999).

Today, the Chinese government supports the pesticides industry by subsidizing raw materials imports (although this type of assistance is being reduced), tax exemption, lower costs for raw materials allocated through the central planning mechanism as well as preferential electricity rates and bank loans. The government appropriates RMB 2.5 billion (US$ 300 mil.) per year in working capital for chemical fertilizer and pesticide production. It also allocates RMB 100 mil. (US$ 12.04 mil.) to the development of new equipment for pesticide production and continues to back companies which run at a loss by converting losses into bank loans.

The government production plan for 1996-2000 aimed to meet domestic agricultural requirements by the year 2000. Priority was given to the adjustment of the amount of various types produced, development of scientific research, more efficient types, formulation, increase in the proportion of herbicides and germicides as well as the modernisation of older facilities. In line with the trend in a number of other state owned industries, the government can establish large transnational company groups and corporations with overseas partners and encourages exports (US Embassy 1996).

e. Industry Structure and Problems

In the 1990s, the Chinese pesticides industry faced a grave crisis which revealed structural shortcomings and threatened the long-term survival of the sector as a whole. In contrast to the global pesticides industry which has become highly concentrated, the Chinese pesticides industry is extremely widely scattered (CCR 16/11/99). There are nearly 400 pesticide synthesis facilities and over 1000 pesticide processing companies (Shubao 1999). Most of the products are manufactured in very-small to medium-size companies which are either privately or collectively owned. In addition, there are some state owned enterprises (Rozelle 1999).

The majority of these pesticides factories are severely handicapped by problems such as: small size, outdated production techniques and low level of automation. In addition, their consumption of natural resources and energy is excessive, they create serious pollution and their economic returns are relatively low compared to foreign producers. Many "made in China" pesticides are of inferior quality and many are merely imitations of foreign products (CEIS 1998). Although there have been some improvements in recent years, the source of the problem still remains: fake products[4], substandard formulations, unlicensed production, lack of testing equipment in factories, confusing labeling, absence of minimum standards fixing quality targets and too many distribution channels leading to a certain degree of confusion (US Embassy 1996).

Insecticides hold an excessive share among pesticides as a whole and most of them are too toxic. In 1997, highly toxic pesticides held an overall share of 36 percent of total pesticide output in China (CCR 16/11/99). Since very few Chinese technicians strive to develop new pesticides, a number of products are obsolete and no longer available on the world market (CEIS 1998). Rich provinces, such as Shanghai and Guangzhou have started to restrict the use of toxic pesticides, such as methamidophos, and the replacement of other highly toxic pesticides has been put on the agenda throughout the country.

It follows that the Chinese pesticides industry is under pressure to accelerate product restructuring and make a concentrated effort to develop suitable alternatives. Should it fail to do so, it will find itself in an extremely unfavorable position and may well be obliged to surrender a substantial market for high-tech and new-tech pesticides to foreign companies (CCR 16/11/99).

Chinese industrial production shows little regional specialization and lacks integrated structures. This is a legacy inherited from the era of a planned economy. In 1994, the regional cross-section structure of industrial output showed that each major industrial group was located in virtually every province. Furthermore, the size of these companies was also remarkably similar across provinces (Anjali 1994). Production capacity was not exploited to the full and this would seem to be a chronic problem and by 1998 capacity utilization had sunk to below 25 percent (CEIS 1998). Excessive supplies on the pesticides market over several consecutive years led to a dramatic price deterioration and created unhealthy competition.[5] While prices sank, producers started to accept transport charges on their own account and launched their own sales promotion activities.

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[4] It has been reported that the quality of pesticides can change over time, e.g. when demand rises some producers increase the quantity sold, while reducing active ingredient concentration. (Jin 1999).

[5] E.g.; since 1995, the price has dropped 52 percent for glyphophate technical powder and around 25 percent for methamidophos.

Pesticide prices hit an all-time low in 1998 when the Asian financial crisis led to a stagnation in exports (CCR 16/7/99).

A number of pesticide producers have been running at a loss for years, but can still survive thanks to the backing of the state banking system which converts their losses into loans. The result is that unviable companies continue to operate. In the long run, they will be obliged to accepted heavy charges to pay off these debts. At the same time, higher labor costs have led to an increase in production costs. In recent years, technology has not been a cost item. However, due to the commercialization of the state sector, which also includes the research institutes, pesticide producers are now obliged to pay technology and development fees for the use of the technology they need so badly (CCR 16/7/99).

f. Investment Activities of Multinational Companies

The country is increasingly looking for Western capital to assist it in modernizing its crop protection industry (ASIAFAB 6/1994). To combat the existing problem of outdated domestic industrial technology, and in line with the government's overall industrialization strategy of substituting imports by domestic goods or promoting production for export, China has started to seek investments from multinational pesticides companies. In return, foreign companies gain access to the Chinese market which they were hitherto unable to penetrate with direct imports from abroad. To this end, the Chinese partner in their joint venture helps them get a foothold in the Chinese pesticides distribution system. To date, foreign companies have not been permitted to engage directly in trade within China, the only exemption being the direct marketing of a share of those goods which they manufactured in the country (Chemical Research Group 1999).

The position of foreign investment was clarified by new regulations which were announced in April 1995: companies with 100 percent foreign ownership are prohibited in the pesticide sector, technology transfer must be ensured, Ministry of Chemical Industry approval is essential (US Embassy 1996). The Chinese government only approves joint venture projects which help improve the technology of the pesticides industry and introduce new types. The establishment of new plants which will compete directly with existing producers by manufacturing the same pesticides is not welcome. In each project, the Chinese partner in the joint venture must contribute a substantial share of the investment equity. 70 percent foreign ownership is admissible for plants which produce new pesticides. Those which manufacture existing pesticides using advanced technology must be at least 50 percent Chinese owned (Shubao 1999a)

City and provincial governments use tax relief and other incentives to encourage agrochemical producers to set up plants in China, e.g. Shanghai has been campaigning aggressively to attract international chemical firms to its special economic zone (Thiers 1994).

In recent years, joint venture pesticide companies have played a significant role in improving the overall status of the Chinese pesticides industry. New products and new processing technology, packaging methods, management mechanisms and marketing strategies have all been introduced from abroad. Several joint venture companies[6] have been established to produce herbicides, insecticides and feed additives.

When these projects are implemented and production gets under way, production technology for certain pesticides will attain advanced world level (Shubao 1999a).

In 1997, 15 international agrochemical companies[7] with investment interests in China formed an alliance called Crop Protection Association of China (CPAP). Its purpose is to assist Chinese organizations such as the State Bureau of Petroleum and Chemical Industries, the Ministry of Agriculture and the Chinese Pesticide Association with the introduction of advanced crop protection technologies. Activities will focus on the promotion of the responsible use of crop protection technology, facilitation of research and development in this area, and the protection of related property rights (CEIS 1998).

5.2 Market Structure and Policy

5.2.1 Domestic Chinese Pesticides Market

a. Overview

Distribution channels are confusing and even chaotic. This is due to the rapid expansion of an inadequately regulated free market superimposed upon a socialist tradition of state-owned enterprises and five year plans (Thiers 1997). There are three different paths by which pesticides get from the factory or port of entry to the farms: the state distribution system, the formal free market and the black market (Thiers 1994).

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[6] In 1996, Zeneca Agrochemicals planned to invest US$ 80 million to set up a herbicide plant in Nantong to produce praquant (Gramoxon) with a capacity of 6'000 tons per year (PANNA 6/96). The same year, the Ministry of Chemical industry signed cooperation agreements with Dupont, Novartis, Bayer, BASF and Rhone-Poulenc and joint ventures were established with Dupont, Novartis, Zeneca Agrochemicals and AgroEvo to produce herbicides and insecticides. Monsanto signed an agreement with China Agricultural University to provide US$ 100'000 for five years for undergraduate scholarships. (US Embassy 1996). Du Pont produces the rice herbicide Londax (Bensulfuron methyl) for domestic and export markets (Thiers 1994).

[7] These include: AgroEvo, American Cyanamid, BASF, Bayer, Dow, Du Pont, Elf Attached, FMC, Monsanto, Novartis, Rhone-Poulenc, Rhom and Haas, Sumitomo, Uniroyal and Zeneca.

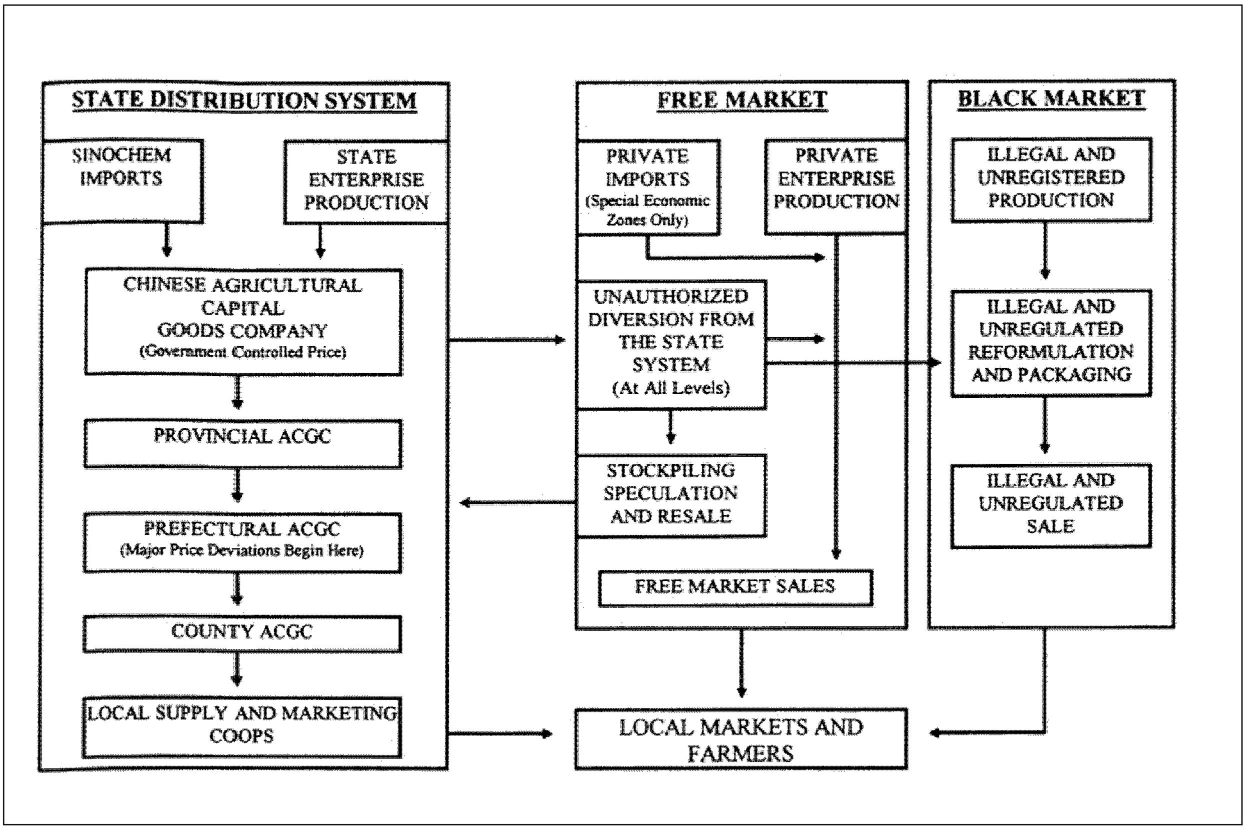

Figure 5-2: The Pesticides Distribution System in China

Source: Thiers 1997

The state distribution system is the traditional distribution channel for agricultural inputs and is owned and controlled by the government. The formal free market consists of the officially acknowledged market channels of other institutions, including free market sales transacted by pesticide producers, private and collective companies, agricultural technology promotion units and agricultural crop protection units. The black or informal market intermingles with the two other channels but operates beyond state control and also sells unregistered pesticides.

At farm level, there are three major retail channels for pesticides: 1. direct sales from production companies; 2. agricultural means of production corporations and 3. agricultural technology promotion units and crop protection units (Rozelle 1999). While agricultural means of production corporations still hold the major market share, other distribution channels are gaining in importance.

b. State Distribution System

Prior to 1980, pesticide production and distribution was controlled by the Ministry of Chemical Industries and the Ministry of Agriculture. Pesticides were allocated through provincial, prefectural, and county agencies in accordance with state production plans (Thiers 1994). The structure of this system still exists today. However, it now functions in a more market-orientated manner. While the government exercises very little control over domestic pesticide production, distribution is almost entirely supervised by the state-owned monopoly of Agricultural Supply and Marketing Co-operatives ASMC (Rozelle 1999). This state supply system is formally organized as a hierarchical chain from producer to local distributor: state-owned enterprises sell agricultural chemicals to the national ASMC in accordance with prices and amounts fixed by state plans. Chemicals are then bought and resold through ASMCs at provincial prefecture and county levels. Collectively-owned companies and other domestic pesticide producers enter the market at lower levels. Finally, local ASMCs buy chemicals from the county ASMCs and sell them directly to the end user (Thiers 1997).

The quantities and types of pesticides supplied by the ASMCs are defined in advance on the basis of pest infestation forecasts or experience. In order to combat sudden pest plagues, local cooperatives are expected to submit a special request to a superior level cooperative in advance, to ensure that the local cooperative has appropriated amounts of pesticide in stock should an outbreak occur (Dunli 1991).

In the past, the system proved to be extremely inflexible. Allocation decisions were made regardless of the varying needs from one region to another and from one year to the next. This was particularly problematic when sudden pest outbreaks necessitated the modification of distribution quotas.

Attempts to maintain low prices through administrative action frequently led to shortages. As central authorities were able to cap the price of goods, each distribution level was officially permitted to increase prices by maximum 10 percent. However, the central enforcement capability diminished as chemicals moved along the distribution system. Distributors frequently added transport and other miscellaneous fees to jack-up prices. The artificially low price at the point of manufacture canceled any incentive to produce, leading to shortages and greater opportunities to realize higher prices at lower levels.

In recent years, it has also not been unusual for agricultural chemicals to be diverted out of the state supply system and onto the free market where prices are not regulated. Unauthorized distribution links are ubiquitous at all levels and proliferate at lower levels. Local ASMCs frequently purchase pesticides direct from manufacturers and manufacturers sometimes sell pesticides to circulation units at various levels or even set up their own sales offices on site in various locations (Thiers 1997).

Chemicals imported by the China National Chemical Import and Export Commission (Sinochem) also enter the supply system via the ASMC channel (Thiers 1997). As ASMCs prefer to market domestic products, farmers are not supplied with brands manufactured by international firms. This has led to the situation in which Chinese farmers would be willing to pay higher prices for modern, imported, reliable, high-quality pesticides but cannot obtain them as they are cut off from other market channels. Accession to the WTO will oblige China to allow competition in domestic markets. This may well lead to an opening of the distribution system to foreign brands of pesticides (Rozelle 1999).

c. Other Distribution Channels

Up until the mid-1980s, prices in China's state owned industry were rigorously controlled. They were gradually decontrolled in subsequent years. Initially, this only involved the production that exceeded the planned quantity, but it was later extended to cover other produce.

Since the mid-1980s, considerable progress has been made in replacing planned allocation by price mechanisms. Although the state withdrew from allocation and pricing decisions, it still maintained its interest in distribution. In fact, the share held by the state sector in distribution even increased in absolute terms between 1985 and 1994 (Anjali 1994). In the pesticides sector, state owned ASMCs still continue to play a dominant role in pesticides distribution (Rozelle 1999).

Anjali (1994) detected a significant convergence between plan and market prices in the early 1990s. In spite of the rapid reduction in price controls, regional price differences still persisted between producer and consumer goods, suggesting spatial segmentation within the internal market (Anjali 1994). Even now, markets for both goods and factors of production still show signs of regional fragmentation. In many provinces, there has been a decline in the interprovincial share of trade flow in relation to total retail trade. At the same time, external trade and inflows of outside investment have increased in most provinces. The lack of a uniform national market combined with monopolistic behavior has created provincial barriers inhibiting the circulation of pesticides (US Embassy 1996).

Nevertheless, there is still an increase in the pesticides being distributed outside of the official state distribution system. Since the mid-1980s, shortfalls in government revenues have led to new fiscal policies including budget cuts for all agricultural extension units and crop protection agents. At the same time, they were granted permits to sell chemical inputs. Agricultural technology promotion units and agricultural crop protection units sell pesticides and their market share is increasing (Thiers 1997). Extension agents at county and village levels sell pesticides directly to farmers in addition to fulfilling their role as agricultural advisors. As a result of government budget cuts, agricultural universities and research academies have set up pesticide production and sales facilities to maintain their own budgets, sometimes as joint ventures with foreign corporations. This situation encourages agricultural scientists and extension workers to recommend the use of chemical inputs (Thiers 1994).

Some pesticides are distributed without government registration. This black market system relies on personal connections and corruption. Frequently, a village leader or wealthy farmer with well-placed family connections can acquire large amounts of pesticides from government or private factories or warehouses to sell locally. There are also reports of the production of "home-made" pesticides formulated from chemicals obtained through various channels (Thiers 1994). These local brands are recommended by word of mouth and are distributed through local dealers (Jin 1999).

5.2.2 Foreign Trade

a. Market Protection Measures

In the past, the Chinese domestic pesticide market was strongly protected by an autarchic policy enforced by instruments such as import licenses, import quotas and tariffs. While the import license system was abolished in 1996, the import quota system is still in force today. With a quota of US$ 200 mil. in 1998, it has become the major non-tariff protection measure. Since 1999, import quotas have been administered by the State Economic and Trade Commission (CCR 16/11/99).

In the 1990s, tariff rates on pesticide imports were reduced significantly. Although the current average weighted tariff rate for imported chemical products is 22.5 percent, compared to 4.7 percent in developed countries and 13 to 15 percent in developing countries, it is much lower for pesticides: 3 percent for bulk materials, 6 percent for formulated insecticides and fungicides and 5 percent for herbicides. In addition, a further 13 to 17 percent value added tax is levied on imported bulk materials (CCR 16/11/99). The low tariff rate on pesticide imports reflects the effective impact of the existing import quota.

If China joins the WTO, the first thing it will have to do is abolish its import quotas. Import tariffs for pesticides will not be affected seriously as they are already relatively low. However, tariffs for raw materials and intermediate chemicals for pesticide production will have to be reduced to a far greater extent. Some producers will certainly benefit from lower production costs for intermediary chemicals and facilitated access to export markets. However, the unrestricted entry of foreign products onto the Chinese market will represent a serious challenge for the majority of Chinese pesticide producers many of whom are not competitive since their production costs are higher[8] due to the small size of their factories, their use of obsolete technology and the low quality of their products (CCR 16/11/99). When the principle of fair trade takes effect, the Chinese government will be obliged to stop supporting firms which run at a loss and sell their products below production costs. As a pre-emptive measure, domestic producers have asked for an increase in tariff rates to protect the development of the Chinese pesticide industry (CCR 16/11/99). The Chinese pesticide industry will be obliged to develop and introduce new technology if it is to achieve long-

8 E. g. Chinese producers can produce Chlorpyriphos for roughly 56'000 Yuan, while production costs for the inventor,. Dow Chemical, are only around 40'000 Yuan.

term competitivity. Finally, both the population and the environment will benefit from cleaner technologies and products (CCR 16/11/99).

b. Import and Export Quantities

Chinese pesticide imports have increased steadily since the early 1960s. When BHC and DDT were abolished in 1983, the Chinese government sanctioned a significant increase in pesticide imports to prevent any adverse effects on agriculture. That was when China became the world's major pesticide importer (Shubao 1999). There was a decline between 1985 and 1987, after which Chinese pesticide imports maintained a high level, roughly US$ 300 mil. per year. As production capacities expanded, Chinese pesticide exports increased steadily from almost zero in 1961 and to an all time high of US$ 383 million in 1998. While the average annual growth rate was a mere 5.8 percent between 1960 and 1989, it increased to 19.1 percent between 1990 and 1998. In 1995, Chinese insecticide exports were valued at US$ 109.3 mil. and included products such as gammexane, DDT, organophosphates and aluminum phosphides. The import value of herbicides amounted to US$ 93.3 billion (PANNA 1996, US Embassy 1996).

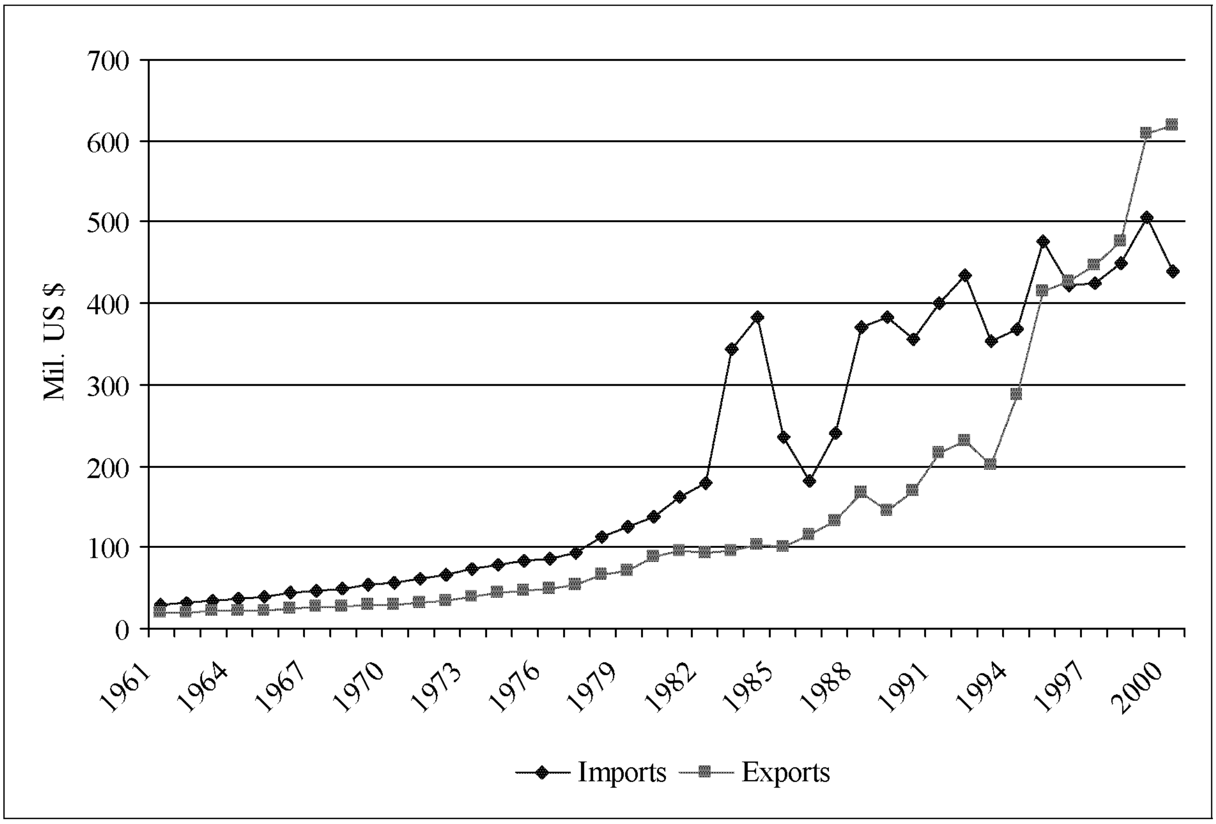

Figure 5-3: Chinese Imports and Exports of Pesticides 1961-2000

Source: FAO Stat 2003

5.3 Pesticides Demand in China

a. Quantities of Pesticide Demand

Aggregate pesticide consumption has increased steadily since 1952 (Fan 1997). There was a marked decrease in the amount of pesticides used following the official abolition of DDT from the Chinese market in the early 1980s (Rozelle 1999). This was compensated for, to a certain extent, by imports and more efficient application practices (Fan 1997). However, there was a steady rise in the consumption of other pesticides during the 1980s and 1990s and, finally, the highest ever application rates were recorded in the late 1990s (Rozelle 1999). Since the early 1980s, the cost share held by pesticides in agricultural production has remained relatively low, namely in the region of one percent of total production cost.

These figures do not reflect the variances between different crops (Fan 1997). Farmers' expenditure on pesticides has risen in line with ongoing increases in overall agricultural production costs.

Today, Chinese pesticide application rates are among the highest in the world (Thiers 1994). In 1997, the total sown area amounted to 123 mil. ha, of which 83 mil. ha. were treated with pesticides. This corresponds to pesticide adoption on 67.5 percent of total sown area (NBS 1999). The quantities applied vary from quite low in some regions to extremely high in others (e.g. Widawsky et al. 1998). Official domestic output amounts to 407'000 tons with net exports accounting for 143'000 tons. Total consumption of active ingredient was around 264'000 tons in 1998 (CCR 16/11/99). It is difficult to quantify the size of the Chinese crop protection market with any degree of precision.

Estimates in 1994 varied from $500 million to well over double that figure. Official estimates were about $850 million (ASIAFAB 6/94). Insecticides dominate the Chinese pesticide market and account for nearly 60 percent of total sales, while fungicides and herbicides account for about 20 percent each (ASIAFAB 6/94).

b. Determinants of Pesticides Use

In the early 1990s, government subsidies for pesticides were cut and this led to an increase in pesticide prices at farm level (Thiers 1994). The gap between the prices of agricultural commodities and inputs continued to widen, forcing the government to reinstate pesticide subsidies in certain cases. This included the issue of pesticide purchase vouchers for farmers who were willing to grow crops such as cotton, which are of great importance but susceptible to pest damage. However, a return to large-scale pesticide subsidies is beyond the government's financial capacity. Agricultural commodity prices did not increase to the same extent as those of pesticides and the cutback in government subsidies finally led to a decline in pesticide use between 1991 and 1993 (Thiers 1997).

There has been a steady increase in the demand for grain. Official policy still aims to maintain China's grain self-sufficiency status at around 95 percent and obliges farmers to expand their grain output even further (Ikegami 1997). The scope for reclaiming new arable land is extremely limited and therefore any significant growth in domestic grain production must be generated by yield improvements or by reductions of the acreage devoted to other crops, such as cotton and rapeseed.

It follows that any further increase in grain production will probably create a greater demand for agricultural inputs such as pesticides to protect grain crops from infestations (Wang Q. et al. 1996).

Plant protection is carried out by plant protection stations at various levels and locations throughout China as part of the agricultural extension system. The work is performed by plant protection experts at various categories of Plant Protection Stations (Qiu 1998). The Ministry of Agricultural coordinates extension work at national level. Formerly, there were four main areas of extension: plant protection, soils and fertilizers, seeds and agricultural technology applications. They are now combined into one unit, the National Extension and Service Center of Agricultural Technology, which is subdivided into 20 sectors (Yuan 1998). However, most provincial agricultural departments still have the original four extension areas. At county level, Service Centers of Agricultural Technology run extension stations for crop protection. In towns and villages, there are agricultural technology centers employing seven to eight people, while in rural areas the heads of the small villages are responsible for both agricultural production and extension work, albeit not in an official capacity (Yuan 1998).

In the past, low salaries coupled with inadequate working and living conditions discouraged plant protection experts in the extension stations at lower levels. Opportunities to refresh or improve their knowledge of plant protection were rare and many left to take up other professions. Consequently, there are not enough competent plant protection technicians available for deployment in local extension stations (Qiu 1998). Lack of proper advice on the use of pesticides may further aggravate their negative side effects and diminish their effectiveness. As plant protection stations are dependent on their pesticide sales, they have a vested interest in advising farmers to apply the greatest possible quantities (Thiers 1993). Experts have advised China to establish a unified pest prevention and control system including the import, development and promotion of advanced application equipment and improvement of training in the handling of pesticides (US Embassy 1996).

In 1993, a survey was conducted on labor intensive rice production in Zhejiang and Jiangsu provinces on the Yangtze River Delta which is one of the world's most productive rice growing regions (Widawsky et al. 1998). Owing to the low per capita availability of land, farmers in this region have traditionally produced extremely high rice yields through the intensive application of labor. Pressure on rice yields has increased due to the region's growth in population and high state procurement rates. Good off-farm labor opportunities in the region have depleted the availability of labor leading to a shift towards intensified use of purchased inputs to meet the demand for high yields. Local leaders and farmers have been compelled to adopt agricultural research system achievements, such as the introduction of modern agricultural technology including fertilizer responsive varieties and pesticides. Consequently, farmers in both Zhejiang and Jiangsu have increased their use of chemical fertilizer by about 5 percent per year. Pest infestations have always been a feature of China's rice production. However, they became chronic when fertilizer responsive varieties were adopted in the 1960s and have continued to be a problem ever since. For example, every season during the period 1985 to 1991, Jiangsu and Zhejiang experienced 1.5 to 2 attacks by the four major rice insect pests and one outbreak of disease. According to local officials, 15 to 35 percent of total crops would have been lost had pesticides not been used during that period. Even with their use, farmers still suffered 3 to 13 percent losses.

As the threat of pest-induced crop losses rose during the 1960s and 1970s, the government gave priority to the availability of chemical pesticides. By the 1980s, land-poor farmers in eastern China were applying pesticides regularly and at levels which were among the highest in Asian rice production (Edwards 1986). In Widawsky's survey, average insecticide application rates were nearly double that of lowland irrigated rice systems in the Philippines, where serious impacts on both health and the environment have been linked to pesticide use (Rola and Pingali 1993). These high levels of pesticide use may also affect natural predators and lead to the development of pesticide resistance. Chinese field and laboratory studies have revealed diminished effectiveness of pesticides when high rates are applied (Chu and Zu 1987, Su et al. 1991).

By the late 1970s, a number of Chinese breeders had succeeded in developing pest resistant rice varieties. However, as agricultural planning placed emphasis on the development and expansion of farm chemicals, host-plant resistance was assigned a secondary role. The breeding of host-plant resistance may lead to a yield/resistance trade-off although it is commonly strongest in cultivars with lower maximum-attainable yields (Khush 1987). Although back-crossing with high-yielding varieties can minimize this trade-off, agricultural officials in eastern China indicated that this had not always been completely successful. In Jiangsu and Zhejian, farmers adopted a wide range of varieties with host-plant resistance to insects and diseases between 1985 and 1991. However, producers continued to use pesticides at high rates which led to a deterioration of the resistance bred into the newly released varieties. Consequently, a substantial share of the varieties sown suffered from diminished host-plant resistance. The average decline in resistance for all varieties is still considerable which justifies concern about China's ability to maintain the current levels of host-plant resistance of its rice cultivars (Widawsky et al. 1998).

Calculations on pesticides and host-plant resistance productivity in relation to rice production in Zhejian and Jiangsu provinces showed that pesticides are probably overused. Production elasticities for insecticides are low and even negative in the case of fungicides. Pesticide use is therefore inefficient in terms of allocation and generates costs which surpass the returns gained from higher yields. The reasons for this situation may be risk-aversion on the part of the farmers or the fact that they are inadequately informed about the productivity of pesticides. On the other hand, the productivity achieved with host-plant resistance to insects is positive, but resistance to disease had a negative impact. This indicates a rapid deterioration of the effectiveness of disease resistant varieties and the yield/resistance trade-off. Finally, the elasticity of substituting host-plant resistance for pesticides showed that improved host-plant resistance can be accompanied by decreases in insecticides with no loss in production (Widawsky et al. 1998).

In northeast China,[9] weed control is performed manually as a rule by hoeing or in some cases using animal traction or a small tractor. Herbicides are occasionally used for wheat and linseed. However, they are always applied in rice production which has become popular since mid-1980s. This is consistent with rice weed control practices throughout China and consequently it is the most frequently treated crop in the country. In northeast China, family land allotments often range from 1 to 2 ha. Hand weeding is therefore feasible, but time consuming and expensive as new opportunities exist for secondary employment outside agriculture. Industry is relatively widespread in southeast China and there is less land available per farm. This is why farmers in this region often take advantage of the opportunity to work in a factory to supplement their agricultural income and thus tend to apply pesticides instead of weeding by hand. Agricultural production on state farms[10] benefits from a higher level of mechanization than family farms. Since herbicides have become readily available, they are used for most weeding operations. Herbicides are also used on military farms[11] as these farms have to pay the army for labor (Su and Ahrens 1997).

c. Application Constraints

Chinese agriculture must overcome several difficulties relating to pesticides: many farmers are illiterate and ignorant about the correct storage and application of pesticides. Surveys have shown that over 90 percent of the farmers do not really understand the proper application methods (US Embassy 1996). As the

9 Su and Ahrens 1997 analyzed herbicide practices in the temperate climate zone of Northeastern China. The season is 100-160 days, rainfall ranges from 40 cm in the East to 70 cm in the West and single-crop agriculture is practiced.

10 Typical state farms in Heilongjiang provinces cover extensive areas, often from 50'000 to 100'000 hectares, although some farms are even larger.

11 Military farms are smaller than state farms, generally ranging from 500 to 2000 hectares.

quality of pesticides is not reliable, farmers often exceed the recommended dosages (Jin 1999). The hand sprayers commonly used in China are obsolete from a technological point of view, are made of inferior raw materials, have inadequate atomizing properties, are subject to severe leakages and achieve uneven spraying results. It follows that application effectiveness is 10 to 15 percent lower than that achieved in developed countries (US Embassy 1996). Currently efforts are being made to convince farmers that they should invest in more efficient equipment (Qiu 1998)

Widespread pesticide resistance has become a serious problem for Chinese farmers since these products have been introduced. Natural predators have suffered from the excessive, inappropriate levels of insecticides used in rice production[12]. As a result, farmers have been forced to increase dosages, which, in turn, has led to the development of pesticide resistant pests. As farmers apply high levels of pesticides, newly introduced resistant varieties rapidly lose their pest resistance property. This trend can be observed in all varieties and has led to concern about China's ability to maintain the current level of host-plant resistance in its cultivars (Widawsky et al. 1998).

Pesticides were applied in the cotton bollworm infested region of Hebei province. However, the attempt failed because the pesticides destroyed beneficial insects which were used early in the season to combat other pests. In addition, the production plots were extremely small, which made coordination difficult (Thiers 1993). In 1993, cotton bollworm had become so resistant to pyrethroid that the government had to restrict pesticide application. As an alternative, organophosphates were applied as often as three times per week. In the end, cotton production became economically unprofitable in this region due to ongoing resistance which necessitated the application of ever greater amounts of pesticide. In spite of procurement obligations, farmers simply refused to grow cotton. For example, in the early 1990s, cotton farmers in Hebei could expect gross sales to bring in roughly US$ 400 per acre while pesticides cost as much as US$ 150 (Thiers 1994). In the remote Southwest of China, farmers earn about US$ 290 per acre and year for rice with costs of roughly US$ 130 (Thiers 1994). High, subsidized prices was the only course of persuading farmers to continue producing cotton (Thiers 1993). Major difficulties also occur with fungicides. There are serious problems here because farmers are reluctant to apply fungicides before symptoms appear, and the development of resistance has become quite serious, too (Kidd 1997).

d. Pesticides Poisoning

There is a long history of pesticide poisoning. Following the introduction of organophosphates in the 1970s, numerous cases of poisoning led many farmers to

[12] E. g. in Zhejiang and Jiangsu province.

refuse to use pesticides. Chinese extension agents conducted workshops and radio campaigns to reassure them that pesticides were an essential element of agricultural modernization and that dangers to health could be avoided by taking simple precautions (Thiers 1994).

Pesticides now enjoy widespread acceptance in the farming community. However, researchers with experience in the extension service report that cases of poisonings and even deaths continue to occur, often due to unauthorized mixing of pesticides or illegal production and use of unregistered chemicals (Thiers 1994). In 1996, Chinese pesticide companies were still selling highly hazardous chemicals for domestic use and export. In 1995, 48'377 cases of pesticide poisoning were reported, including 3205 fatalities. 90 percent of these cases were caused by insecticides and 91 percent were organophosphates. Over 61 percent of the organophosphates poisoning were due to parathion, methamidophos and omethoate. Jiangsu, Shandong and Anhui accounted for 76 percent of total national number of cases of poisoning. The reporting system on which these figures are based has not been established in all areas of the country and in some regions reporting is limited. For this reason, the actual number of poisonings is estimated to be 60 percent higher (PANNA 6/96).

In addition, consumers also suffer from poisoning due to pesticide residues. In many cases, these residues in agricultural products greatly exceed the relevant standards, which constitutes, in turn, a threat to exports. The use of substandard, prohibited pesticides is still widespread and represents an increasing threat to consumers (US Embassy 1996). Indeed, pesticide contamination in Chinese export products received international publicity when several cases of methamidophos poisoning were registered in Hong Kong. Consumers had eaten contaminated vegetables imported from China (SCMP 22/8/92). Laboratory tests on vegetables in Hebei frequently indicated the presence of residues which exceeded legal limits and in 1991, 101 cases of pesticidal residues in vegetables in Guangdong were reported, as well as 2086 cases of poisoning in the same year (Thiers 1994). By the mid-1990s, only 6.3 percent of vegetable-producing areas were free of pesticide pollution (US Embassy 1996). Although it was officially prohibited to use parathion on vegetables, it could still be bought to contend with cotton bollworm. Consequently, farmers continued to use it on vegetables. In addition, the fields are so small in China that even if it was only used on cotton, pesticide drift onto vegetables is almost inevitable (Thiers 1994). The Ministry of Health established residue standards for the very first time in September 1995. However, they do not cover all 27 types of pesticide residues (US Embassy 1996).

e. Integrated Pest Management and Chinese Ecological Agriculture

Integrated pest management is a time-honored practice in traditional Chinese agriculture and as pesticides were scarce up until the late 1950s the government placed emphasis on traditional pest management (Chenxiang 1988). The search for plant-based pesticides was encouraged in the 1950s by a popular campaign to eliminate flies, mosquitoes, rats and fleas. Unfortunately, the movement was short-lived, because the initial response was over-enthusiastic and failed to live up to expectations. Stocks of relevant plant species were rapidly depleted in the following years. The Dibrachys Cavus parasite had been used to control the pink bollworm in cotton since the 1950s and the production of microbial pesticides, such as Bacillus Thuringiensis, reached a peak in the 1960s. Activities in the biology sector were limited and only one of the many factories remained in production after 1982 (Plimmer and Li 1990).

Following a series of problems which arose in the 1960s due to excessive use of insecticides, a combined approach incorporating biological control and integrated control based on the agri-ecosystem gained prominence in the 1970s. A large number of entomologists and research workers went to the People's Communes and worked with the peasants on the development of mass cultures, the release of parasites and the production of microbial insecticides. From 1975 onwards, the government actively promoted Chinese Integrated Pest Control (IPC) programs which became a synthesis of ancient Chinese tradition and modern science with inter-cropping and inter-planting practices designed to encourage the presence of natural enemies. Given a substantial rural labor surplus, it was possible to use chemicals more selectively (Chenxiang 1988). IPC programs were neglected in the early 1980s, only to be revived in the 1990s when pesticide resistance became widespread and there was evidence of growing concern regarding pesticide residues and groundwater contamination (US Embassy 1996). Agenda 21, China's sustainable development plan, deals with these matters in the chapter on agriculture (US Embassy 1996).

The development of environmental awareness among China's growing middle class and the increasingly obvious environmental and economic impact of chemical agriculture are laying the foundation for a pesticide reform movement. In spite of the overuse of pesticides and the absence of an organized pesticide reform movement, it would appear that members of the government are becoming increasingly aware of the negative effects of pesticides. In addition, Chinese consumers, especially the growing urban middle class, are becoming alarmed about pesticide residues in food. In fact, some consumers now prefer vegetables with insect damage because they believe it to be less contaminated with chemical poisons.

In 1990, the Ministry of Agriculture established the Green Food Development Center which introduced a "Green Food" label for goods produced under environmentally-friendly conditions. Green food certification prescribes that the use of chemicals must be kept within certain limits. In future, it is expected that these limits will be gradually reduced until production is totally chemical-free. Green Food certification includes standards for soil and water quality, additive-free processing and environmentally-friendly packaging. However, these criteria are not yet available as written standards. In addition, only state farms are certified for "Green" label production, which leads to the suspicion that the government is merely exploiting this label to make state farms profitable (Thiers 1994).

Recently, academic journals and government policy have given priority to "Chinese Ecological Agriculture" which aims to combine modern science with traditional agricultural technology in an attempt to establish an ecologically appropriate and functionally regenerative agricultural system. This means emphasis is placed on labor intensive methods, the correct use of agrochemicals, intercropping practices, exploitation of on farm energy and reduction of external inputs, which all represents a radical departure from to the modernization paradigm which has dominated agricultural policy since the mid-1970s. In line with the government's strategy to promote "Chinese Ecological Agriculture", foreign bio-pesticides companies have commenced business activities in China[13].

Summary

Chinese Pesticides Industry

In the early 1960s, China produced virtually no pesticides at all. By 1997, it was the world's second largest producer. DDT and BHC were itnroduced in the 1950s, organophosphorus insecticides in the 1960s, and organophosphates became popular in the 1970s. Several pesticides, such as BHC and DDT, were taken off the market after the mid-1980s and replaced by more advanced products. The production of herbicides and fungicides expanded considerably after the early 1980s. In recent years, modern varieties have been introduced and investments from foreign companies have helped to promote the rapid expansion of production. Today, a large number of the pesticides produced in China are obsolete as they are excessively toxic. They have been taken off the market in most other countries. It follows that the Chinese pesticides industry is under heavy pressure to adjust its product mix.

Until recently, research on pesticides was the exclusive domain of public research institutions which relied mainly on public research funds. However, these institutes were too small to formulate their own pesticides. Instead, they concentrated on imitating existing pesticides. In the 1990s, central government decided to set up two large research units with formulation capability. This coincided with intensified protection of intellectual property rights.

Up until the mid-1980s, the Chinese pesticides industry developed in line with demand. Small scale pesticides factories developed quickly during the boom of rural industries in the 1980s and gained considerable market shares. Today, the Chinese pesticides industry is highly fragmented, consisting of nearly

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[13] EcoScience Corp entered into long-term collaboration with the Institute of Biological Control of the Chinese Academy of Agricultural Science in Beijing, Ecogen Inc. received approval to sell their Bacillus Thuringiensis products.

400 synthesis enterprises and over 1000 processing companies. In addition, bottom-of-the-scale kitchen factories are also in operation.

In the 1980s, the Chinese state-owned pesticides companies, gradually released from the state stranglehold, started operating on a commercial basis. The industry's serious shortcomings had become apparent by the 1990s. Most of China's pesticides factories face severe problems: for example, they are too small, use outdated production techniques, incur excessively high production costs and produce too many insecticides as well as toxic, unlicensed, substandard products. Finally, excess market supplies have led to a drastic price deterioration so that a large number of companies are now running at a loss. Nevertheless, state-owned factories still receive loans from state banks as they are not allowed to go bankrupt.

China has been trying to attract foreign pesticides companies since the mid-1990s. However, if they wish to enter the Chinese market, they are only allowed to operate in joint ventures and are restricted to the manufacture of new products with new technology or of goods for export.

Pesticides Market

In the days of the planned economy, pesticides were distributed by the monopolistic, hierarchical system of Agricultural Supply and Marketing Cooperatives. This is still the main distribution channel for agricultural inputs. However, since the system operates with planned distribution quotas, the supply is too inflexible to respond to farmers' requirements. A parallel system of formal and informal market channels emerged in the mid-1980s. Farmers now can also buy pesticides directly from companies, extension workers, research institutions and local traders. This market is outside the control of the official registration system. It is therefore possible for unknown labels with unregistered, self-made pesticides of dubious quality to get onto the market. Interprovincial trade barriers protect local producers from competition.

Chinese pesticide imports have increased steadily since 1960, they leapt in 1984 when BHC and DDT was banned and have continued at high levels since the late 1980s. The expansion of domestic production has led to a steady increase in exports, with a significant rise in recent years. China finally became a net exporter of pesticides in 1994. Imported pesticides enter the Chinese market through the state marketing channel. However, they are subject to discrimination which favors domestic brands. As long as import tariffs remain low, import quotas represent the principal means of limiting imports. China's WTO membership is expected to improve market access for imported pesticides

Pesticides Demand

With the exception of a short decline in the early 1980s, aggregate demand for pesticides increased constantly from the 1950s onwards, reaching 260'000 tons valued at 500-800 mil. $ in the late 1990s; 60 percent of sales were insecticides.

Large scale pesticide subsidies were cut in the early 1990s, though they remained in force for grain and cotton. The use of pesticides likewise increased in line with the introduction of high yield varieties and grain biased rotations. Recent economic progress in some areas has led to labor shortages in other regions. This has been compensated for by an increase in the use of inputs such as pesticides, while herbicides have replaced manual weed control.

In the mid-1990s, pesticide application rates in East China were among the highest in the world. Estimates show that they were overused. This has led to widespread insect resistance, e.g. in rice and cotton. Pest resistant varieties have lost their resistance due to over-intensive cultivation methods and continued use of pesticides. In addition, farmers and consumers have suffered severe pesticide poisoning.

Integrated pest management has a long-standing tradition in China and was actively promoted by the government as a complement to pesticide application. After being neglected in the early 1980s, it experienced a revival when pesticide resistance became a serious problem in the 1990s. In recent years, two integrated food production labels haver been introduced: "Green Food" which applies mainly to products from state farms and "Chinese Ecological Agriculture", introduced in the household farming sector.

Part II

Determinants of Pesticides Use in China

6 Economic Theory of Pesticides Use

This chapter discusses how microeconomic production theory is used to derivate pesticides demand function. In the microeconomic framework the foundation of agricultural production is a production function with output vector Q which is defined to be a function $F(\bullet)$ of the productive inputs S.

$$Q = F(S) \tag{1}$$

Until the 1980s pesticides were treated in microeconomic theory in the same way as other yield increasing inputs such as fertilizer. Several studies showed, however, that treating pesticides the same way as other productive inputs will inevitably lead one to overestimate the productivity of pesticides.[1] This is because pesticides are damage control agents. Unlike standard factors of production, i.e. land, labor, and capital, they do not increase potential output directly. Instead, by reducing damage, they increase the share of the potential output that is actually realized. It was to account for this difference that Lichtenberg and Zilberman (1986) introduced the concept of damage abatement function. According to this, output is not only a function of directly productive inputs, but also a function of prevented pest damage:

$$Q = F\left(S, G(X)\right) \tag{2}$$

$G(X)$ is the damage abatement function, a proportion of the destructive capacity of the damaging agent eliminated by the application of damage control agents X. Some inputs do not only increase yield directly, they affect damage (Saha et al. 1997):

$$Q = F\left(S, Z\right) G\left(Z, X\right) \tag{3}$$

with Z denoting the vector of inputs that interact with the damage control agents within $G(\bullet)$. Finally alternative pest abatement agents (H) such as pest resistant varieties, mechanical barriers, and manual or mechanical removing of weed are distinguished from pesticides (X). A summary is given in Figure 6-1.

1 Carrasco-Tauber and Moffit 1992, Babcock et al. 1992, Blackwell and Pagoulatos 1992, Chambers and Lichtenerg 1994, Carpentier and Weaver 1997, and Saha et al. 1997 compared the two forms and found a high overestimation of pesticides productivity in the model without separate damage abatement function.

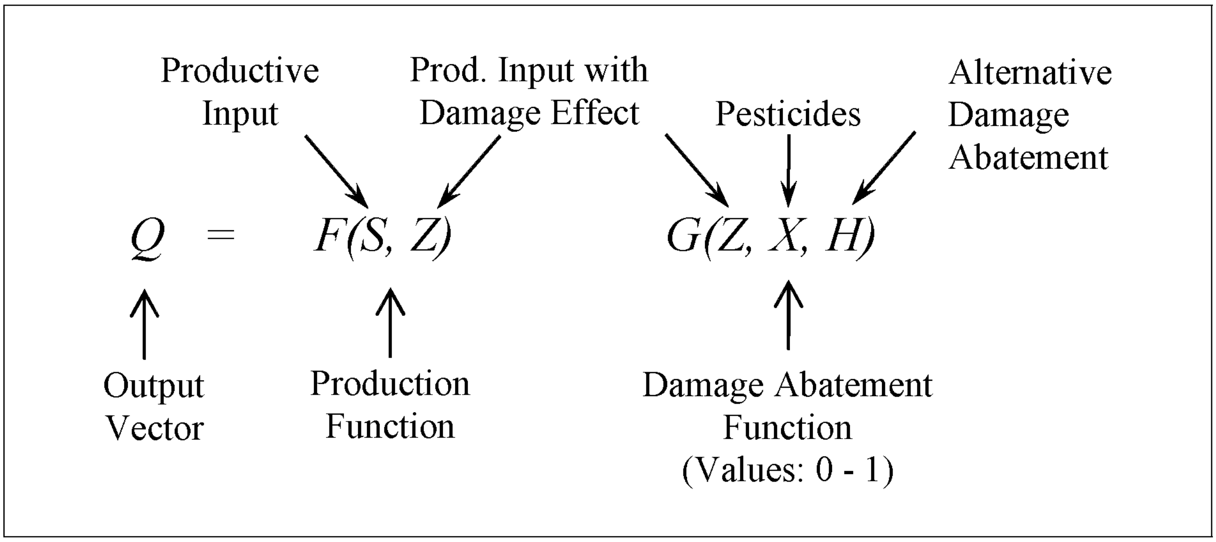


Figure 6-1: Production Function with Damage Abatement

When decomposing output by the output of n different crops q_i:

$$q_i = F_i(S_i, Z_i)G_i(Z_i, X_i, H_i) \tag{4}$$

The profit function derives:

$$\max \Pi = \sum_{i=1}^{n} p_i F_i(S_i, Z_i)G_i(Z_i, X_i, H_i) - p_s S_i - p_z Z_i - p_h H_i - p_x X_i \tag{5}$$

Assuming a decreasing marginal effect, the maximum profit $\max \Pi$ with respect to pesticides use is achieved at the place where the marginal revenue of a unit change of pesticides use equals the pesticides price:

$$\partial \sum p_i F_i(S_i, Z_i)G_i(Z_i, X_i, H_i) - p_s S_i - p_z Z_i - p_h H_i / \partial X_i = p_x \tag{6}$$

From this we can see what pesticides demand depends on:

$$X_i \rightarrow p_x,\ F_i(\bullet),\ G_i(\bullet),\ p_i,\ p_s,\ p_z,\ p_h \tag{7}$$

This is the potential output defined by the production function $F_i(\bullet)$ with yield increasing inputs S_i, Z_i, abated damage defined by the damage abatement function $G_i(\bullet)$ with damage abating inputs Z_i, X_i, H_i, and all prices i.e. prices of pesticides p_x, other inputs p_s, p_z, p_h and output p_i.

Production function $F_i(\bullet)$ defines the effect of inputs on potential output. A high effect of inputs causes a high potential output which enhances marginal profit of pesticides use. The production function is mainly determined by the agro-ecological conditions on different farms. Under favorable agro-ecological conditions pesticides use tends to be higher. Yield increasing inputs S_i, Z_i enhance potential output within the production function. The more inputs are used the higher is the marginal profit of pesticides use.

Damage abatement function $G_i(\bullet)$ defines pest pressure and the potential effect of different damage abatement measures on pest damage. Natural environment, crop variety, local pest pressure and pest management history are the main factors determining the fundamentals of the damage abatement function. High damage means high potential effect of pesticides, while, conversely, no pesticides will be used if there is no damage at all. Alternative pest management measures H_i and productive inputs that affect pest damage Z_i determine the damage condition on which pesticides can potentially have an effect. They can also reduce damage to such an extent that pesticides become redundant.

Price levels, finally, are the most important factor determining pesticides use. High quantities of pesticides are applied if pesticides prices p_x are low, output prices p_i .are high, productive input prices p_s are low, or costs of alternative pest management measures p_h are high. Farmers typically enjoy high output prices and low input prices if markets are well developed, infrastructure is in a good shape, and the non agricultural economy is in a sound condition.

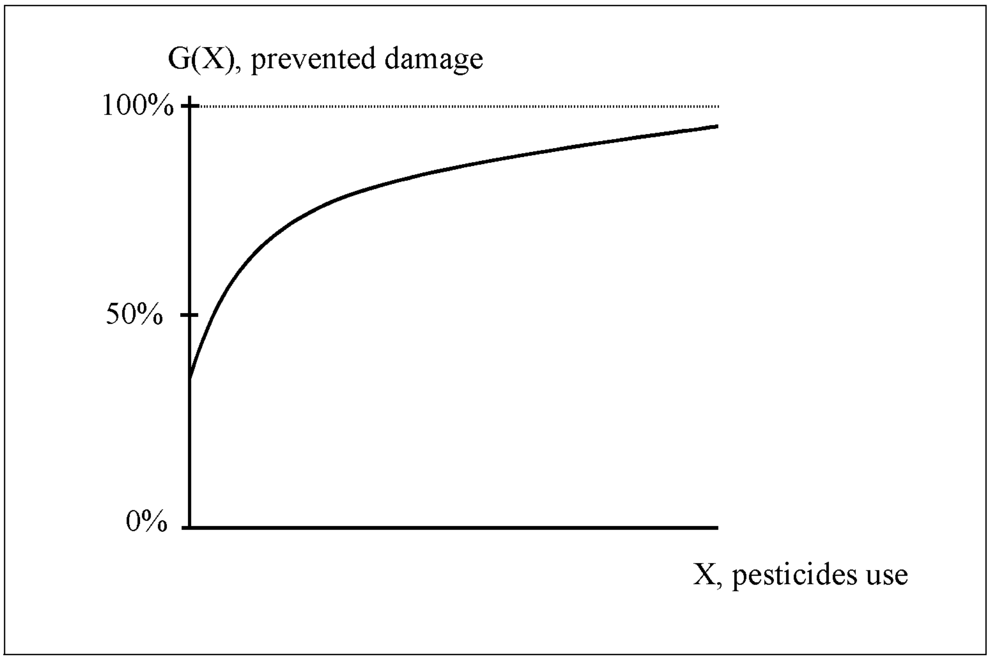


Figure 6-2: Damage Abatement Function and Pesticides Use

The above functions can also be depicted graphically. Figure 6-2 is a damage abatement function with quantity of pesticides used on the x-axis and damage on the y-axis. The intersection point of the damage abatement function with the y-axis is the share of output that would be lost if no pesticides were used. The curve of the damage abating function illustrates the assumption of declining marginal damage abating effect as pesticides use increases.

Figure 6-3 illustrates the marginal effect of pesticides use on damage. Here the x-axis is pesticides use and the y-axis is marginal damage abated by pesticides use ($\partial G(X)/\partial X_i$). The curve shows declining effects of pesticides use.

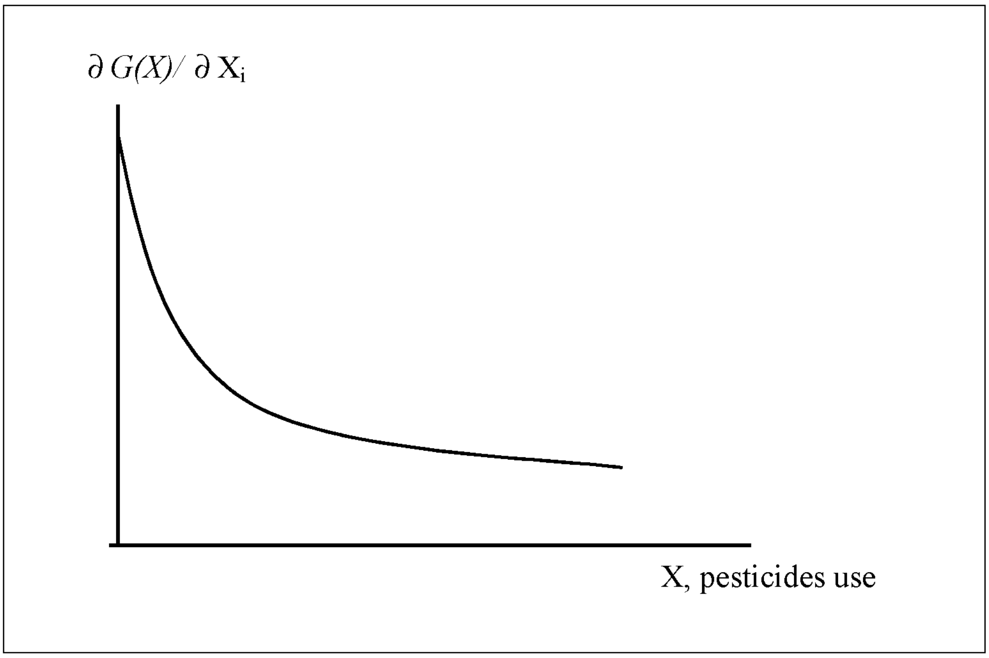


Figure 6-3: Marginal Effect of Pesticides Use on Damage

Marginal damage abated by pesticides use can be translated directly into marginal profit MR_X (Figure 6-4). Inserting the marginal cost MC_x which equals the pesticides price line P_x, the intersection point equals the maximum profit at optimal quantity X_i of pesticides applied at price P_x.

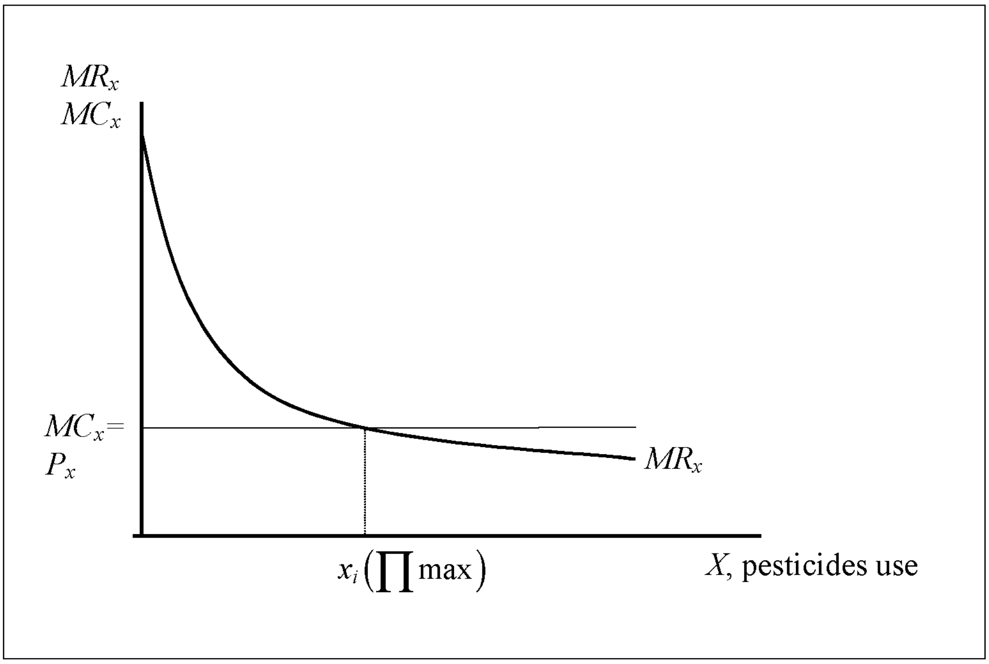


Figure 6-4: Profit Maximization and Pesticides Use

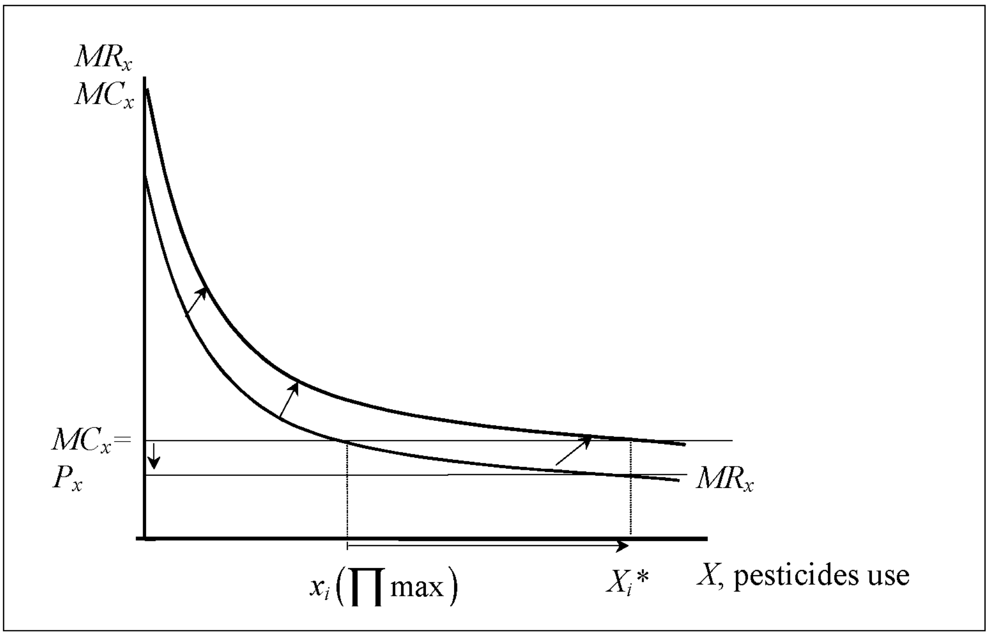


Figure 6-5: Optimal Pesticides Use: Increasing Marginal Profit and Declining Pesticides Prices

If marginal profit increases or the pesticides price declines, maximum profit is at a higher level of pesticides use.

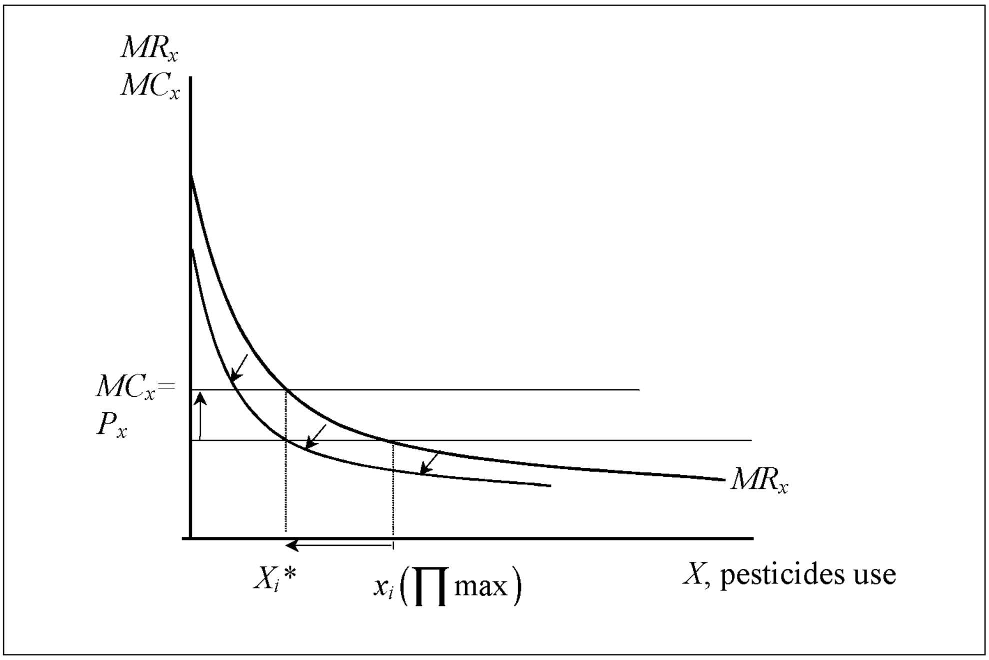


Figure 6-6: Optimal Pesticides Use: Declining Marginal Profit and Increasing Pesticides Prices

If marginal profit declines or pesticides price increases, fewer pesticides are applied at the optimal level.

7 Factors Affecting Pesticides Use and Trends in Chinese Agriculture

Economic theory on the use of pesticides provides the rationale for the farmers' decision-making process when they wish to apply pesticides.

There are three key decisions each crop-farm is confronted with:

- crop choice,
- technology choice with corresponding productive inputs, and
- adequate pest management.

These three decisions are interdependent: Farmers choose a certain combination of crops with the corresponding mix of productive inputs. Each crop is susceptible to a set of pests. There are alternative methods of dealing with each pest: one possibility is the use of pesticides – and even here, farmers can choose between different products containing different substances.

Figure 7-1 illustrates this web of contexts: each level is a choice between several options which are determined by the economic, agricultural, institutional, as well as farm specific environment. Bearing this concept of farmer behavior in mind, it is interesting to see what evidence can be found in the Chinese context. Discussion in this chapter is based on the content of Part I.

7.1 Crop Choice

The mix of crops planted determines the set of pests that can potentially occur on a farm. If high value crops are cultivated, fighting pests is more profitable, justifying higher pest management costs and, along with them, a higher use of pesticides.

Figure 7-2 illustrates the output value and corresponding input expenditures of the main crops cultivated in China. Assuming equal pest pressure on the different crops, the net return would be the core factor determining the level of optimal pesticides application in the different crops.

As far as cereals are concerned, the highest levels of pesticides use can be expected from rice. Rice is indeed one of the most heavily sprayed crops in China. It is typically cultivated in wet paddy-fields in a wet, warm, and humid environment which is very conducive to pests. And the conditions are made even more favorable to pests by the heavy use of fertilizer in combination with fertilizer responsive varieties - which are more vulnerable to pests than traditional varieties. In addition, rice cultivation is strongly pushed by the government. Subsidized fertilizer and pesticides are offered to the farmers so that they can achieve the required production quota (Widawsky 1998, Jin 1999).

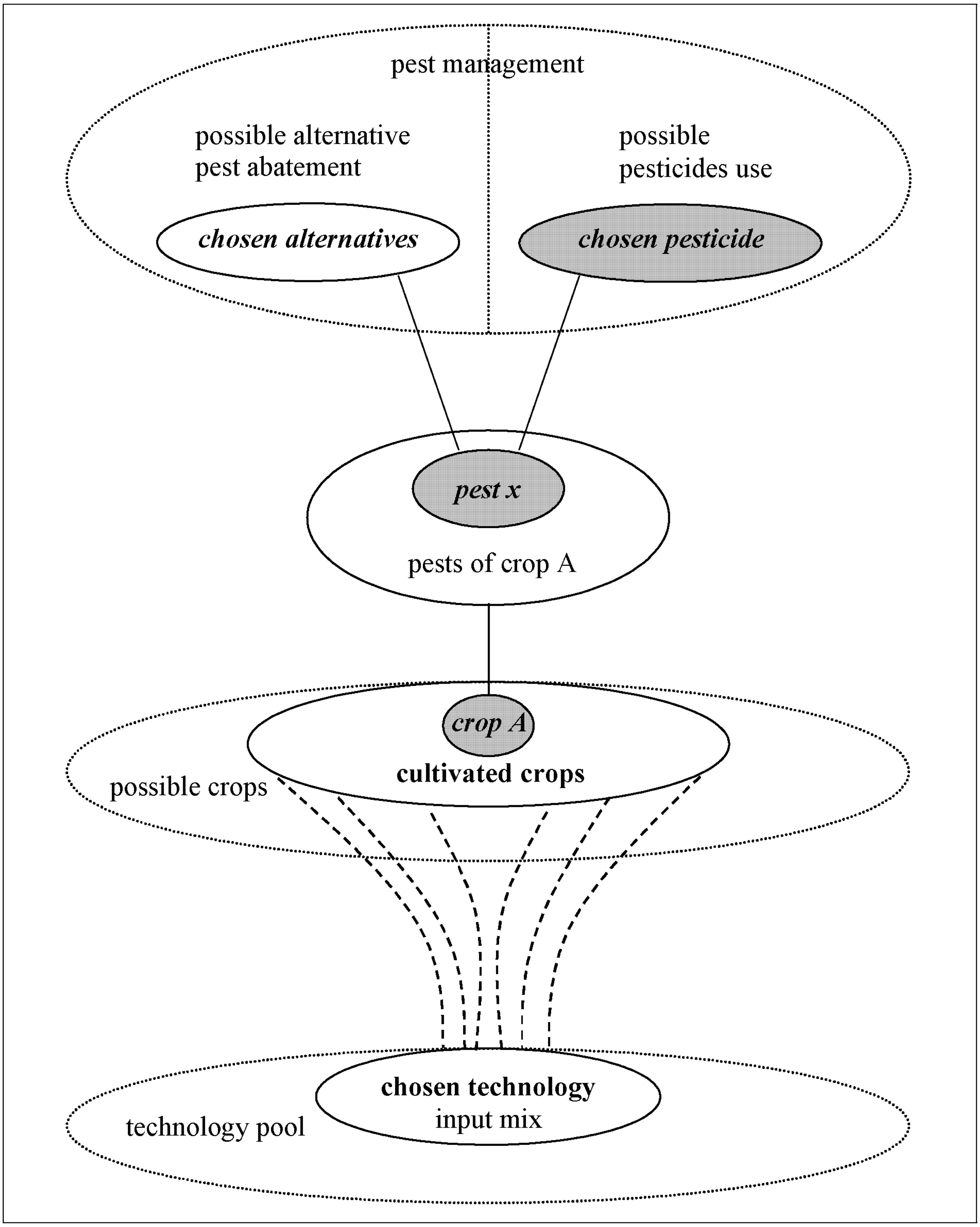
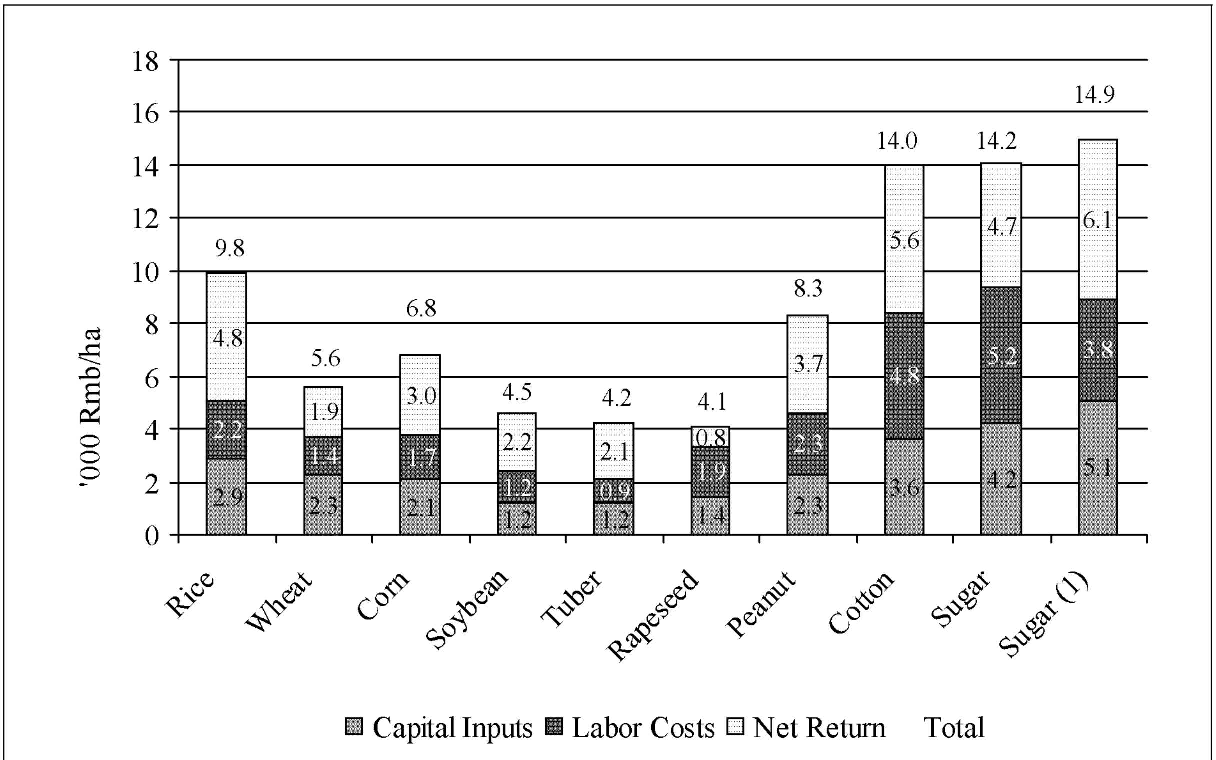


Figure 7-1: Farmers' decision making:
Input Mix, Cropping Mix and Pest Management



(1) Sugar is the average of sugar beet and sugar cane weighted by the extent of their sown area (33% and 66%).

Figure 7-2: Output Value and Input Expenditures of Different Crops in China (1994-96 Average)

Source: NBS 1998[1]

Corn and wheat grow best on dry fields and in temperate climate, where pests grow more slowly than in tropical and subtropical conditions or wet fields. Since corn is more drought resistant than wheat (Yang 2000) we can expect corn will require a lower use of pesticides. Barley, sorghum, millet and oats grow best under marginal conditions. Their requirements in terms of pesticides can therefore be expected to be smaller than those of the other cereals.

While peanuts, with an input requirement which is similar to rice, would also justify high pesticides use, the output value of soybean, rapeseed and tuber crops is much lower, and, accordingly, lower pesticides application can be expected.

Figure 7-3 illustrates crop specific pesticides application in US agriculture in 1997.[2] Although both agricultural production structure and pest infestation are

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1 The data stem from the 1994-96 average of the National Cost of Production Survey which is conducted annually by the State Price Bureau and its county Price Bureau personnel.

2 The data differentiate between 220 individual active ingredients and 87 crops and account for agricultural practice all over the U.S. (Gianessi and Marcelli 2000, www.ncfap.org). These data were aggregated by pesticides type: fungus, insects, weed, and others. In order to make the application of different active ingredients comparable, the aggregate share of planted area treated with pesticides was chosen. In order to make the data most comparable

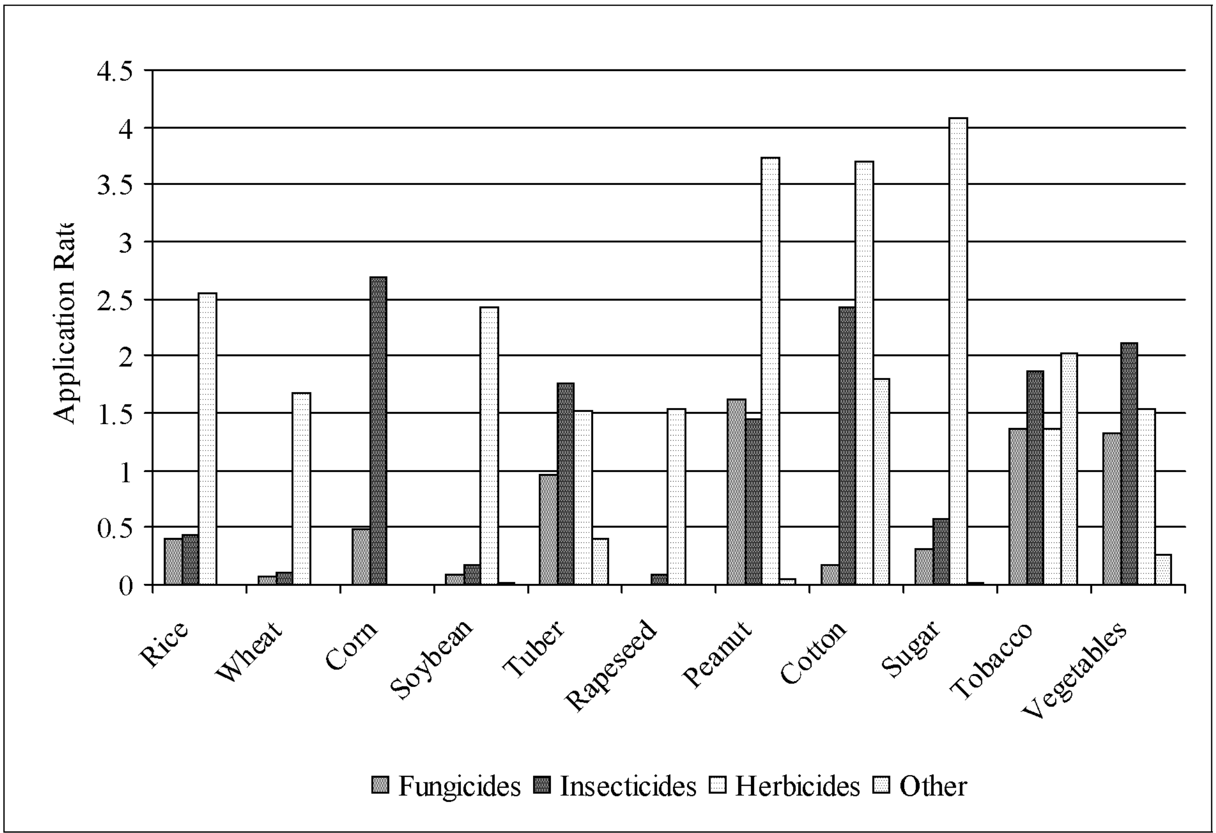

Figure 7-3: Pesticides Application by Type of Pesticides and Crop in US Agriculture (1997)

Source: NCFAP 2000, Gianessi and Marcelli 2000, own calculations

different from China, these data provide an insight into the susceptibility to pests of different crops. The figures on pesticides usage reveal significant differences between different groups of pesticides: compared with other pesticides, the application rates for herbicides are high among all crops. Since weeding is still done manually in China, data on herbicides have to be treated with caution. Still, they provide a picture of where Chinese agriculture will be heading when agricultural structures adjust in the long run, i.e. when agricultural labor becomes more scarce in China. Fungicides and insecticides treatment is high with tubers[3], peanuts, tobacco and vegetables. Cotton is the crop that is treated most heavily with insecticides. This indicates that these five crop groups are the most susceptible to pests.

The goal of Chinese agricultural policy to keep the country self-sufficient in grain continues to the present day. Measures to induce farmers to produce grain in sufficient quantities are input subsidies, output price support, investment in

with the variables considered in the quantitative analysis some crops were aggregated to groups. Single crops were weighted by the corresponding Sown Area in China in 1996.

[3] i.e. potato and sweet potato

agricultural technology coupled with the enforcement of a certain grain production quota. The governor responsibility system forces each province to be self-sufficient. In consequence, the grain procurement quota is higher in provinces where farmers would not otherwise produce sufficient grain under prevailing market conditions. This is typically the case in the densely populated coastal provinces (Johnson 1999; Huang J. et al. 1997; Tuan and Cheng 1999).

Chinese agriculture has a comparative advantage in the production of labor intensive crops such as fruits, vegetables and certain cash crops. The accession of China to the WTO will allow Chinese farmers to export more of these crops, while the import of wheat, rice, feed grain, and oilseed will increase (Anderson and Strutt 1999; Hayes and Fuller 1999; Wang Z. 1997). Farmers in coastal provinces will profit most from this new market environment. On the other hand, farmers in remote areas will find it difficult to gain access to international markets because of high transportation costs. In addition, they will have to compete with imported products when they market their products in coastal provinces (Xiaopeng 1999).

Economic development has led to a dramatic increase in income and has caused a change in consumer behavior. While rising incomes no longer affect the demand for food grain, they still have a positive effect on the consumption of fruits and vegetables. The westernization of diets in urban China is causing a shift from rice to wheat (Huang J. et al. 1997; Ikegami 1997).

Economic conditions are pulling Chinese agriculture away from the production of grain towards the production of vegetables, fruits, and cash crops. The government, with its policy of grain self sufficiency, is fighting against this trend with quota enforcements and incentives (Tuan and Cheng 1999). Opening up foreign trade and relaxing the grain bag policy will increase the overall productivity of Chinese agriculture with the production of fresh products and cash crops in coastal areas and the production of grain and storable cash crops in remote areas. The expenditure on pesticides will increase in line with this development.

7.2 Input Mix

The factor endowment of a farm determines its production potential and with it the yield of the cultivated crops. Increasing the use of productive inputs will lead to higher yields. The high use of productive inputs generally goes hand in hand with high use of pesticides.

a. Land and Labor

Chinese agriculture is characterised by land shortagen high population density and high land productivity (Craig et al. 1997). Yet the loss of land to urban construction could be compensated for by reclaiming new land in Heilongjiang and Inner Mongolia (Ikegami 1997). The attempts by the government to increase the sown area of grain by increasing the number of crops per year is limited by a sharp increase in production costs (Fan 1997a). Only a shift towards high value crops with a short vegetation period – such as vegetables – might help to increase the sown area.

High population density with underemployment in rural areas causes labor productivity to be low in Chinese agriculture. New working opportunities outside agriculture have reduced overall labor input in agriculture and have led to an increase in labor productivity. But off farm wages are rising faster than incomes in agriculture (Huang J. et al. 1997).

Average farm size is extremely small in China. This is, however, typical for the region. Developments in Japan, South Korea, and Taiwan show that these structures will persist. Still, there is a discernable trend towards cooperation in machinery usage and pest management (Carter et al. 1996).

The area quantity of cultivated land will slowly decline in the future. To enhance labor productivity in agriculture, a share of the labor force have to find new work outside agriculture, while the remaining farmers try enhance their income by raising yields and by switching to high value crops. Both trends will increase the use of pesticides.

b. Irrigation

Irrigation is widespread in China and the irrigated area has expanded dramatically in recent years. In regions such as North China and Xinjiang, the natural limit has almost been reached, and the cost of exploiting new water sources has risen (Yang 2000).

In the past, most of the irrigated area in North China used to make use of flood irrigation. Nowadays half of the area is irrigated from wells. Overuse of water resources has started a vicious circle in which the groundwater level sinks as wells are deepened. Only the large scale diversion of water from the south to the north might help to ease the problem. Since the economic profitability of water use is lower in agriculture than in urban usage, the growing urban economy is increasingly taking water away from agriculture (Yang 2000).

These two trends have led to an increase in the costs of irrigation. To overcome this problem, farmers in North China will have to use water more efficiently and adjust their cropping mix towards high value or more drought tolerant crops (vegetables or corn instead of wheat) (Yang 2000).

As the expansion of irrigation has reached its natural limits, agriculture is having to cope within existing conditions. There is a potential for further yield increase by improving the efficiency of irrigation. Provided the profit made from the crops is sufficient to justify the necessary investmentst, expenses for pest management will also rise.

c. Seed

China has one of the largest research systems in the world. Research has always set great store on increasing the yields of grain. In the past, a steady delivery of new varieties of grain seed contributed considerably to yield growth (Hang J. et al. 1997, Huang J. and Rozelle 1996, Fan and Pardey 1995). The government's strong support for agricultural biotechnology (Holland 2000) is likely to lead to a flow of new varieties that are more stress tolerant (cold, drought, salinity, acidity), and which will produce substantially higher yields in regions with marginal agronomic conditions. New host plant resistance might, however, make pest management essential.

Weak intellectual property rights, regional trade restrictions, limited market access, administered prices, and declining government funding have caused a crisis in the Chinese seed industry, and this has inhibited more innovation. The opening up of markets and better enforcement of intellectual property rights will enhance private investment and technology transfer from abroadt, helping to kick-start the innovation process (Pardey et al. 1996).

The effect of the ongoing innovation process on the use of pesticides use is double-edged. On the one hand, higher yields will justify an increase in pest management efforts. But given that new varieties are also less susceptible to pests, declining pest pressure will at the same time reduce the need for pesticides.

d. Fertilizer

The Chinese government strongly supports the use of fertilizer in agriculture with government investment in production, tax exemption on fertilizer, tariff exemptions on imports, price controls, and cash subsidies. As this is one of the key elements in the Chinese agricultural policy of increasing yields in grain production, this engagement can be expected to continue. Modernization of the current domestic production in order to achieve better product quality with higher efficiency is under way (Huang J. 1998; World Bank 1997).

Several studies have shown that fertilizer contributed strongly to yield increase in Chinese agriculture in the past and that there is still potential to do so. All the same, application levels are lower than in Japan and South Korea. An increase in the production of high value crops and rising labor costs are likely to enhance fertilizer use (Wang et al. 1996; Fan and Pardey 1996).

Domestic marketing and cross provincial trade are still very much controlled by provincial governments, a situation which leads to inadequate supply (such as a lack of potash) or supply according to performance rather than need. There is a big potential for fertilizer to contribute to further yield increase if supply can be adjustted to real demand needst, and the strongest potential lies in lower usage areas. The liberalization of domestic and foreign trade might open up markets for these regions and remedy the lack of potash. The opening of the markets will also improve the efficiency of the distribution system and lower prices (World Bank 1997).

Since all trends point towards a further increase in the use of fertilizer in order to enhance yields, it is likely that expenditureon pest management will rise.

7.3 Pest management

The choice of which pest management measure to use against a particular pest depends on the price of the different measures available to a farm, as well as on the farmer's knowledge of the effect of different measures.

In China a large proportion of the pesticides produced are old fashioned, low efficient, toxic pesticides which are competing with modern products which are more efficient and less toxic (CEIS 1998; Cheng 1990; Shubao 1999; CCR 16/11/99). The government supports the production of low efficient products in state-owned enterprises by offering subsidies on raw materials and covering losses (US Embassy 1996). But a situation in which many small scale factories produce the products and pesticides for which there is declining demand, has led to a dramatic oversupply and declining market prices (CCR 16/7/99). The opening up of markets and the reduction of subsidies, as well as the prohibition of old products, will lead to a consolidation of the domestic industry into larger firms producing environmentally sounder products (Shubao 1999/1999a; Rozelle 1999).

The traditional distribution channel, the Agricultural Supply And Marketing Cooperatives, are responsible for allocating pesticides to grain farmers at subsidized prices. In addition, they compete with extension stations and private dealers in selling pesticides to farmers (Thiers 1994/1997; Rozelle 1999). The market is opaque, without quality control or official approval for products (Thiers 1997). Yet foreign trade is limited. The future is likely to bring the opening up of trade for imports, better enforcement of intellectual property rights, the setting up of a central approval institution and quality control (CCR 16/11/99; Shubao 1999a).

In most of the fertile areas of China, pesticides usage is very high, with widespread negative side effects such as pesticides resistance (e.g. rice and cotton), poisoning of farmers and residues in food (Edwards 1986; Thiers 1994; Widawsky et al 1998; Jin 1999). There is an long tradition of integrated approaches to reducing pests, for example, adequate cropping mix or the use of biopesticides. In recent years foreign companies have entered the country to produce and sell biopesticides. The use of manual labor in pest management against weed and insects is declining rapidly as wages outside agriculture are rising. This is one of the main reasons why the use of herbicides has increased so rapidly in recent years (Shubao 1999; Su and Ahrens 1997). The old tradition of crop breeding together with the Chines government's strong support for biotechnology led to the release of a new wave of host plant resistant crop varieties in the 1990s. This will considerably reduce the need for using pesticides. Herbicide-resistant varieties will help to increase the turnover of certain products. An aversion to biotechnology in export markets might slow down the process of diffusion of certain products.

Insufficient quality standards for the pesticides on the market, declining government funds for extension workers, a lack of qualified extension staff, and the activities of extension farms in the selling of pesticides have all led farmers to lose their trust in, and knowledge of the effects of, a certain number of pesticides. The widespread overuse of pesticides, with all the concomittant negative side effects, have been the consequence (Widawsky et al. 1998; Jin 1999). An independent pest prevention system and enforcement of certain quality standards will help farms to regain trust and to turn towards more sustainable pest management practices.

Critical domestic consumers and export demand (mainly for fruits and vegetables) are forcing farmers to adopt more environmentally sound production practices (SCMP 11/8/92; Thiers 1994; CCR 16/11/99). The governement is lending its support to this trend by enforcing the prohibition of certain products on the market and by supporting labeling initiatives such as "Green Food" (IPM) or "Ecological Agriculture" (organic) (Thiers 1994).

Current conditions in the Chinese pesticides market are promoting a high use of pesticides. Many of them are outdated products that have been prohibited in industrial countries and are no longer traded internationally because they are toxic and persistent. The use of pesticides in grain production is directly pushed by the government which enhances pesticides use in grain. Rising labor costs tend to increase the use of herbicides. Although there are no signs of a dramatic change in the short run, there is a long term trend towards integrated pest management, environmentally sounder pesticides of reliable quality and host plant resistant biotech crops.

8 Empirical Approach to Analyzing Pesticides Use

This chapter discusses the empirical model that was calculated to estimate the determinants of pesticides use. The chosen approach is a pragmatic solution to the dilemma of finding an empirical model that, on the one hand, calculates with available data and considers as many aspects as possible, but, on the other hand, is as consistent as possible with theory.

8.1 Chosen Data and Empirical Model

Empirically estimating the demand for pesticides in line with the concept of damage abatement function requires a daunting amount of data: exact information on the quantities and prices of all the inputs used, information on the potential damage to each crop, and information on each pesticide and its effect.

The starting point for the empirical model calculated in this work are the data of the Chinese Agricultural Census 1997. The data stem from the survey of the First National Agricultural Census in China that was conducted in January 1997. The data reflect the situation of Chinese agriculture in 1996. The household data consist of a 1 percent random sample of all family farms in China i.e. 2 million households out of 200 million (NBS 2000)[1]. The household data only include the survey of family farms; the analysis therefore does not account for the use of pesticides on state farms.

The key variable used in this analysis is "share of sown area treated with pesticides". The value of this information is limited to whether a farmer uses pesticides on a certain share of his farm or not. There is no information on the quantity or quality of the pesticides applied. Assuming that pesticides are only applied if there is any pest pressure at all, the variable indicates that there is a certain pest pressure on the farm and that this pressure is reduced by spraying pesticides. If a farm uses no pesticides at all it is possible that this is because this technology has not yet been adopted. From this we can conclude that the variable "share of sown area treated with pesticides" expresses the demand for pesticides as well as the adoption of pesticides. In further discussion this variable will be called "pesticides use".

In addition to pesticides use, the data set includes sown area of each crop, fertilizer use, machinery usage, film cover, farm size, labor input, other economic activities of household labor, as well as age and education of the household head.

1 A one percent sample of the household survey has been published on the website of the Chinese National Bureau of Statistics (NBS). The exact number of households of the original data file is 2'138'275; of which 1'912'661 are engaged in cropping.

Since there is no more information available on pest pressure, yields, or prices, the analysis focusses on the direct relationships between pesticides treatment and the other variables. The core of the model therefore is a linear regression of the following functional form:

$$y^{*} = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k + \mu_i \quad (k = 1,2,\ldots,k)$$

Here, pesticides use (y) is the dependent variable, all other variables are used as independent variables (x).

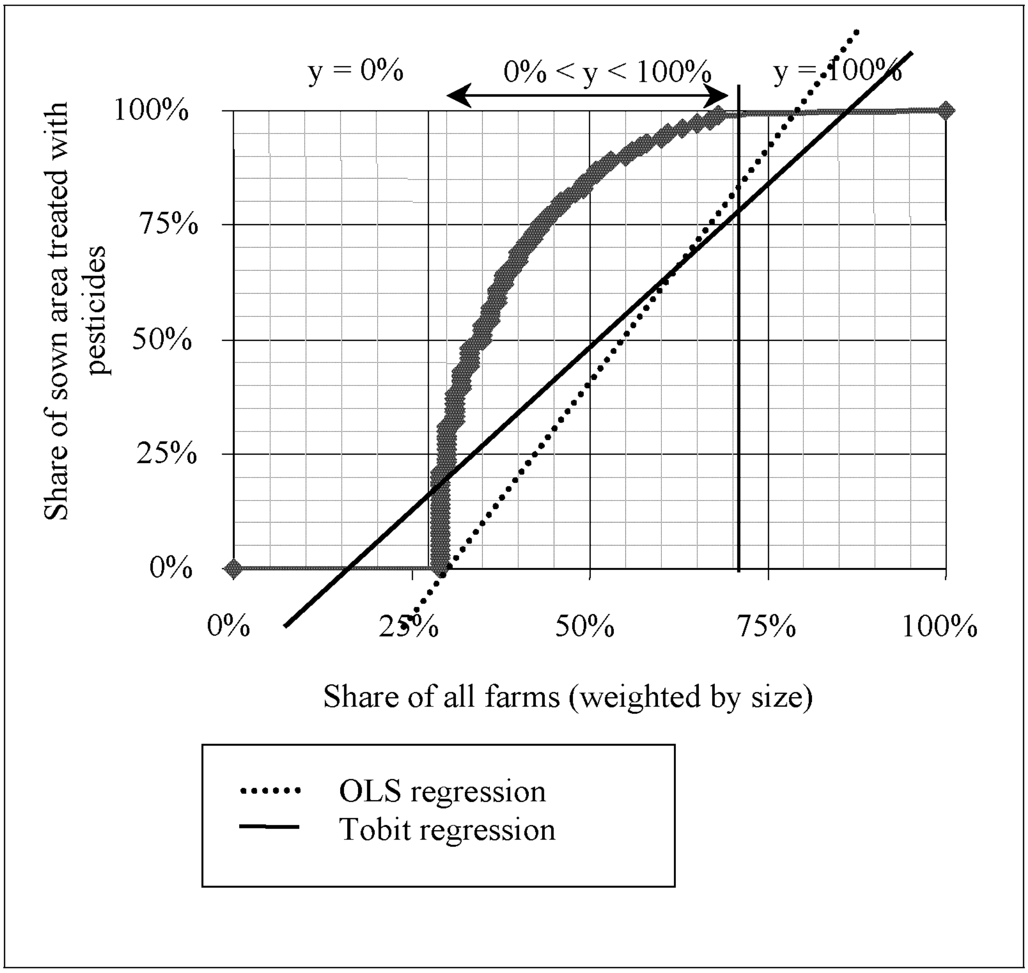

Figure 8-1: Distribution of Pesticides Area on Farms with Different Usage Levels

Figure 8-1 illustrates the distribution of the intensity of pesticide use on all farms weighted by their farm size. The x-axis represents the number of farms weighted by size i.e. the real sown area distributed on farms with different intensity of pesticide use. The y-axis represents the share of total sown area that was treated with pesticides. From this we can see that 30 percent of the sown area is on farms that apply no pesticides at all and 40 percent of the sown area is on farms that treat 100 percent of their area with pesticides.

This distribution has substantial implications on the choice of estimation procedure: estimating the regression with an ordinary least square method (dotted line) would neglect all farms that use no pesticide at all, and understate the farms that treat 100 percent of their sown area. The equation is therefore estimated as a two limit Tobit regression (continuous line) which is a mixture between a probability model for the choice between 0 percent or 100 percent and the distribution of farms that treat more than 0 and less than 100 percent.

The Tobit model was first introduced by James Tobin and has been expanded in several ways since then. Mathematical details of the model can be found in Annex 1. The Tobit model is a linear regression model which can be divided into three parts: a component for upper censoring ($y = 0$), lower censoring ($y = 1$), and no censoring ($0 < y < 1$). The model is estimated applying maximum likelihood procedure. From the calculated β the marginal effect and elasticity are calculated for further interpretation.

The results make it possible to distinguish two different effects: whether a farmer uses pesticides at all and, if he does so, to what extent. In the Tobit model these two effects can be separated in the results by calculating the so-called "McDonald and Moffit decomposition" ratio or adoption ratio. The adoption ratio expresses the share of total estimated effects that can be attributed to the probability that a farmer uses pesticides at all.

8.2. Hypothesis of Explanatory Variables

Having examined the theoretical framework of production theory, analyzed literature on this theory, and found a dataset with the corresponding empirical model to examine the dependency of pesticides use on other variables, it is now important to draft an appropriate hypothesis for the effect of the different variables used in the calculation on pesticides use.

Production theory shows that pesticide use in cropping is affected by a change in net profit determined by yield level, output and input price, pest pressure, as well as the price of the chosen pesticides and their alternatives. Figure 8-2 compares the provincial means of pesticides use, taken from the Census data, with corresponding output value figures from the Annual Yearbook statistics. Here, the theoretical claim that higher output value leads to higher pesticides use is substantiated.

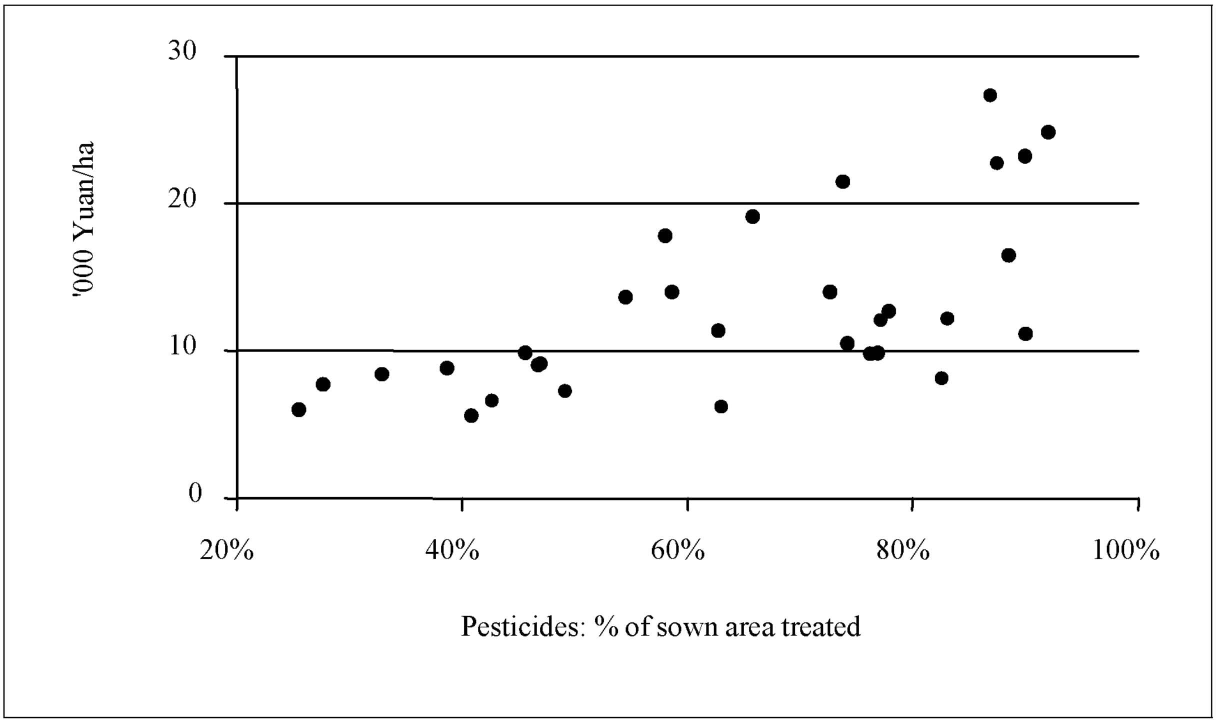

Figure 8-2: Output Value and Pesticides Use (by province 1997)

Source: Census 1997, SBB 1998

The model distinguishes 13 different crop categories: rice, wheat, corn, other grain (barley, sorghum, millet, oats), leguminous crops (mainly soybean), tuber crops (sweet and Irish potato), rapeseed, peanuts, other oil-bearing crops (sunflower, linseed), hemp, tobacco, sugar (cane and beet), vegetables (including melon), other crops. From means of the data we can see that the three main crops, i.e. rice, wheat and corn, cover more than 60 percent of the total sown area. Non grain crops cover only 19 percent of the total sown area. Typical high value cash crops such as vegetables, tobacco, and cotton only make up 8.7 percent of the total sown area. Discussion above (chapter 7 page 137) concluded that it is the cultivation of rice, cotton, tobacco, sugar, and vegetables that justify the highest pesticides application rates. The effect of corn is expected to be somewhat lower than that of wheat and legume, tuber and other grains are considered to be crops with a low output value and are therefore treated considerably less with pesticides than are the other crops.

The results of oil bearing crops are not yet clear. Peanuts are rather drought tolerant, a lower pest pressure can be expected with this crop. Rapeseed is a winter crop which is cultivated in a similar way to wheat. Other oils, which includes linseed and sunflower, also grow under harsh conditions, therefore pesticide use on these crops can be expected to be lower than average.

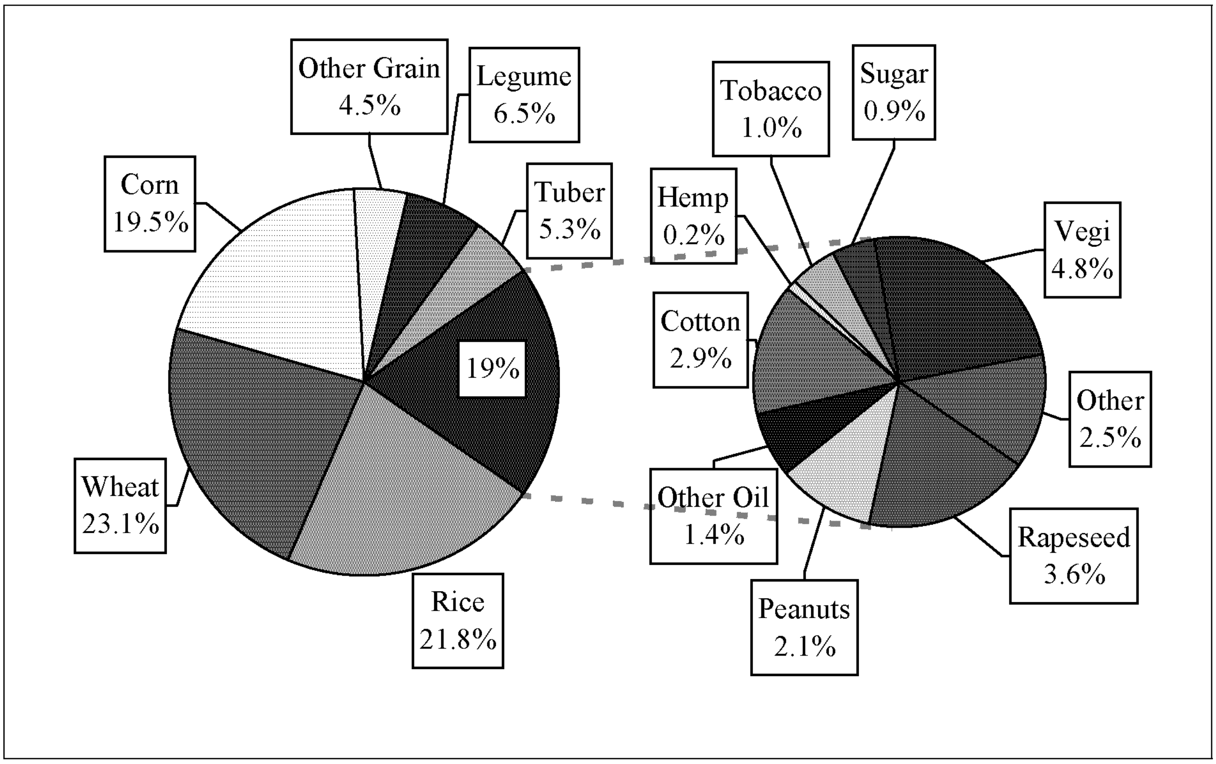

Figure 8-3: Sown Area of Different Crops Cultivated in China 1996

Source: Abstract of the Census 2000

Technical efficiency is higher on large farms than on small farms, mainly due to economies of scale (Huang Y. and Kalirajan 1997). We can expect larger farms to use less pesticide because they have more opportunities to follow a well balanced rotation which reduces pest pressure

Input figures are enclosed in the data in the form of percentage shares of the sown area which have been treated with the particular input. The chosen variables cover the use of fertilizer, machinery including mechanical ploughing, sowing, and harvesting, as well as the use of plastic film cover. Information on irrigation was not available; it is therefore assumed that irrigation is part of the natural environment.

Fertilizer has a similar nature to pesticides. It is a capital input which has been industrially produced and has to be delivered to the farms from outside. From an agronomic point of view fertilizer is best applied if agro-ecological conditions are favorable i.e. if abundant water is available, modern fertilizer responsive varieties are planted, farmers are equipped with enough capital, or have access to capital inputs at attractive prices. Fertilizer is part of the same green revolution package that pesticides are also are part of. From this we can expect that farmers that use fertilizer on a large share of their land are likely to have a higher potential output, stronger pest pressure, and lower pesticides prices. All this indicates a very positive impact on the marginal profit of pesticide use and, with it, a higher pesticides use.

Table 8-1: Variables Definitions and Corresponding Hypothesis

	Expected effect	Unit
Dependent variable:		
Pesticides Use		% of total sown area
Independent variables:		
Rice	+	% of total sown area
Wheat	?	% of total sown area
Corn	?	% of total sown area
Other grain (barley, sorgh., millet, oats)	-	% of total sown area
Leguminous crops (mainly soybean)	?	% of total sown area
Tuber crops (sweet and Irish potato)	?	% of total sown area
Rapeseed	?	% of total sown area
Peanuts	?	% of total sown area
Other oil-bear. crops (sunflower, linseed)	-	% of total sown area
Cotton	+	% of total sown area
Hemp	-	% of total sown area
Tobacco	+	% of total sown area
Sugar (cane and beet)	+	% of total sown area
Vegetables (including melon)	+	% of total sown area
Other Crops	-	% of total sown area
Total sown area	-	Hectares
Fertilizer	++	% of total sown area
Film cover	+	% of total sown area
Ploughed with tractor	+	% of total. Cultiv. Area
Mech. Sown	+	% of total sown area
Mech. harvested	+	% of total Harv. Area
Labor input in cropping	+	Manpower/ha
Other agricultural labor	?	Manpower/ha
Working in industry	+	Manpower/ha
Other off farm labor	+	Manpower/ha
Age of household head	?	Years
School years of household head	+	Years

Calculations on the effect of machinery on agricultural output showed a positive effect.[2] They indicated that investment in machinery not only substitutes manual

[2] Zhang X. and Fan (1999) used the Generalized Maximum Entropy Approach to empirically estimate multi-output production functions and input allocation.

labor but results in work being done that would not otherwise be done. The use of machinery is likely to positively affect pesticide application. Another aspect is that plastic film is used to cover the land in order to extend the period of cultivation period, and as a result of this too, more use of pesticides can be expected.

Two reasons can explain high labor inputs: opportunity costs of labor are low or the farm produces high value labor intensive crops. Both explanations point at a high output value. This is in line with the findings that showed that output elasticity of labor is highly positive for grains as well as cash crops.[2 (p.152)] We can expect, therefore, that farms with high labor input per sown area will tend to achieve higher net returns per sown area, and this in turn may allow for the application of more pesticides. In a situation of underemployment in rural areas this effect will be minor.

High opportunity costs of labor force the farmer to find a way to improve labor productivity, either by substituting labor by capital or by generally enhancing capital intensity of production. This effect has frequently been observed in the literature on the subject.[3] From this we can expect that farms with attractive working opportunities outside agriculture will tend to minimize labor input in agriculture i.e. they will substitute labor by pesticides. In addition they will earn the capital required to buy inputs such as pesticides. But this will only take place if there are no alternative and more profitable investment opportunitiest, such as for example rural industries.

Farmers have an exaggerated perception of crop yield loss due to pest related disease. This is why most farmers do not believe the recommendations and instructions on pesticide product labels: the recommended dosage levels are commonly regarded by farmers as being too low. Farmers with better education tend to perceive expected crop losses more realistically (Huang J. et al. 2000a). It has also been shown that technical efficiency increases in the case of farmers that have a higher education (Huang Y. and Kalirajan 1997). Since older farmers are likely to be more experienced in agriculture, they will probably also manage pests more efficiently. The fact that household heads are older and better educated means that they will tend to produce higher net returns. Educated farmers face higher labor opportunity costs due to their better wages for farm workt, and

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[3] As employment in rural enterprises and urban areas has expanded, the opportunity cost of agricultural labor has risen. The farming sector has became a part-time job in many areas of the eastern and coastal regions of China. This change is likely affect the substitution of chemicals for labor (Huang J. and Rozelle 1996). As opportunity costs of labor increased the application of herbicides increased more than 4 times over between 1985 and 1996. This effect was especially marked in areas where industry boomed (Su and Ahrens 1997). Cross-section analysis of rice farming data in Zhejiang province of 1998 show that opportunity costs of labor are one of the main determinants of pesticides use (Huang J. et al. 2000a). Improved off-farm labor opportunities in coastal China have depleted the availability of labor in agriculture leading to a shift toward intensified use of purchased inputs (Widawsky et al. 1998).

for this reason too it is likely that they will apply more pesticides than younger and less educated farmers. It is possible that the positive effects on the use of pesticides will outweigh the negative.

9 Determinants of Pesticides Use: Results

This chapter presents the results that were estimated applying the Tobit model on the agricultural census data. The model considers all variables discussed in the last chapter as well as a county dummy variable which stands for local conditions such as soil, water, climate, infrastructure, and pest pressure. The samples were weighted by farm size, i.e. sown area.

Two perspectives have been chosen for analysis:

First, the data set of eight sample prefectures were chosen to analyze the effects on actual samples with real and comparable local conditions. These results cannot be generalized but they help one to understand the situation in a real location.

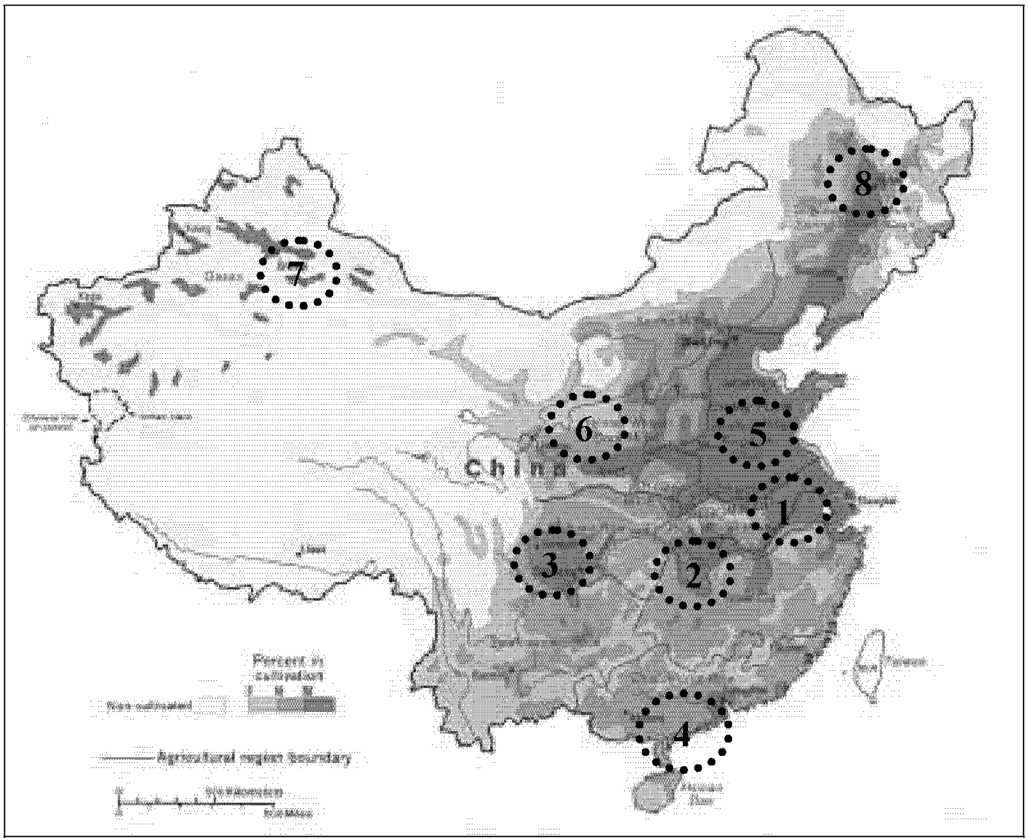
Second, the model is calculated for the whole data set which makes it possible to obtain results that have a whole country perspective and are generally valid for the whole of Chinese agriculture, but have limited information value in actual cases.

The results of each of the different studies are first examined separately. Discussion starts with the means and distribution of the different variables. Then the calculated effects on pesticide use are discussed – less the question whether an effect is statistically significant or not than what magnitude an effect has in relation to potential change in the corresponding variables. The results are summarized in a table at the end of each section.

9.1 Results by Region: 8 Case Studies

Eight prefectures were selected to calculate eight separated case studies, each one taken from a different major cultivation region of China. Agriculture in the chosen prefectures is typical for the respective regions. Although these eight regions do not cover all agricultural conditions in China they represent the most productive part: Yangtze River Delta, Hunan and Hubei Basin, Sichuan Basin, South China, North China Plain, Loess Plateau, Xinjiang, Northeast China (see Figure 9-1).

Analysis starts with a geographic description of the region. This makes it possible to understand the real-life context the farms operate in. Information not covered by the data set was taken into consideration when interpreting the results.



1. Yangtze River Delta: Wuhu prefecture (Anhui)
2. Hunan and Hubei Basin: Yiyang prefecture (Hunan)
3. Sichuan Basin: Dazu, Tongnan, and Tongliang county (Chongqing)
4. South China: Maoming prefecture (Guangdong)
5. North China Plain: Jining prefecture (Shandong)
6. Loess Plateau: Xifeng prefecture (Gansu)
7. Xinjiang: Turpan prefecture
8. Northeast China: Suihua prefecture (Heilongjiang)

Figure 9-1: Sample Regions for Case Studies

Source: CIA 1986

9.1.1 Yangtze River Delta: Wuhu prefecture

The lower reaches of the Yangtze are accompanied on both sides by a vast alluvial plain with changes in altitude of only a few meters. Embracing Anhui, Southern Jiangsu and Northern Zhejiang province, it is one of the country's major agricultural regions with 19 percent of the country's arable land producing 57 percent of its rice and 33 percent of its grain.

Situated in the subtropics, its climate is warm and humid throughout the region with a constant average daytime temperature of over 10° C and no distinct dry and rainy seasons. Typhoons are common in summer and bring heavy rainfall.

The region was originally swamp and has been converted into agricultural land by drainage. The landscape is still characterised by the mesh of land and water. The dense canal network serves irrigation, drainage and transport purposes. Since there are no slopes, all the water has to be pumped from the channels into the fields. But since water is abundantly available it can be pumped individually by each farmer. Nowadays most of the water is pumped by diesel or electric engines. The prevailing ecological conditions are high precipitation, and heavy and wet soils that are difficult to cultivate: indeed, more than 75 percent and sometimes even over 90 percent of arable land is wetland. The density of the agricultural population is extremely high and there is very little land available per capita. The population density and the limited amount of agricultural have combined to produce intensive cultivation with high annual yields per unit area. Despite the fact that this region is on the climatic margin for rice production, it is in this area that the highest yields per hectare are achieved.

On paddy fields crop rotation is an alternation of dry and wet agriculture: one or two rice harvests on wet paddy and one harvest on dry paddy fields during the cold season (mainly wheat or rapeseed). On dry land two crops a year are grown: a summer crop such as maize, cotton or sweet potato and then a winter crop such as wheat, barley, Chinese milk vetch or broad beans.

Figure 9-2: Agriculture in Wuhu

Source: Mueller 1997

The chosen sample area, the prefecturte of Wuhu, is located in Anhui province along the banks of the Yangtze. The data sample comprises 3175 households in four counties.

In Wuhu 88.2 percent of sown area is treated with pesticides with more than 99 percent of farmers applying pesticides. The cropping mix is in line with that of the region: 66 percent is rice, 20.1 percent is rapeseed, 6.7 percent vegetables and 2.2 percent cotton. Average farm size is 0.33 hectares, and crops are harvested twice annuall, leading to an average sown area of 0.67 hectares. Fertiliser is added on 94 percent of the sown area. 50.1 percent of the sown area is ploughed by tractor. With 3.6 persons per hectare of the sown area, labor input in cropping is slightly higher than the national average (3.4 persons/hectare). 47 percent of household labor workin cropping and 38 percent in industry. The most important animals are poultry, mainly ducks, (22.3/ha) and pigs (1.3/ha). Permanent crops occupy only a small share of land.

Table 9-1: Wuhu: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Rice	65.7%	95.5%	+	0.2%	0.1%	**[b]
Wheat	1.5%	15.6%	?	15.2%	0.3%	7.7%[c]
Tuber (Sweet Potato)	1.0%	15.4%	-	-40.9%	-0.5%	0.0%[c]
Rapeseed	20.1%	83.3%	?	-4.7%	-1.1%	9.4%[c]
Cotton	2.2%	14.4%	+	6.3%	0.2%	16.3%[c]
Vegetables	6.7%	91.3%	+	17.3%	1.3%	0.0%[c]
Other Crops	2.7%	28.0%	-	-9.4%	-0.3%	4.1%[c]
Total Sown Area (ha)	0.67		-	-2.7%	-2.1%	1.6%[d]
Fertilizer	93.6%	99.1%	++	55.4%	58.8%	0.0%[d]
Film Cover	1.7%	14.7%	+	29.0%	0.6%	0.0%[d]
Ploughed by Tractor	50.1%	51.2%	+	4.7%	2.7%	0.0%[d]
Labor Input crop. (p/ha)	3.60		+	0.3%	1.1%	7.6%[d]
Oth. Agric. Labor (p/ha)	0.06	2.7%	?	0	0	ns
Working in Industry (p/ha)	2.91	17.5%	+	0.1%	0.2%	5.8%[d]
Oth Off Farm Labor (p/ha)	1.08	40.2%	+	0	0	ns
Household Head: Age	42.5		?	0	0	ns
HH: School Years	6.5		+	0	0	ns
Pesticides Use	88.2%	99.1%				
Adoption Ratio	1.3%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

Estimated results are in line with the imputed hypothesis (Table 9-1). Based on the fact that most farmers use pesticides and that they use them on 88 percent of their land, the overall effects are minor and the adoption ratio is only 1.3 percent. Cropping mix has a significant impact on pesticide use: while the effect of growing vegetables and cotton is strongly positive, a larger area of rice would not raise the current levels of pesticide usage. The effect of most other crops, including rapeseed, is negative. All the same, the overall effect of crop choice is minor. For instance, doubling the current area devoted to vegetables would extend the area in which pesticides are used by only 1.2 percent. More significant is farm size: large farms are more likely to use fewer pesticides. Even here, the effect, while noticeable, is negligible. However, in the current situation, it is very likely that very small farms will increase their average sown area per farm, and a farm that increased, say, from the current 0.66 hectares to 2 hectares would reduce pesticide use by 6.3 percent.

All capital inputs have a significantly positive impact on pesticides use. The use of fertilizer has the strongest effect on pesticides use. But tractor and film cover have a positive impact, too. Since the current level of fertilizer usage is already very high, the potential impact of a further increase is limited.

For example, even if all farms fertilized 100 percent of their sown area, pesticides use would only increase by 0.6 percent. An increase in ploughing to 100 percent of the sown area would cause an increase in the use of pesticides in the order of 1.3 percent. A triplication of film covering would increase pesticides use by 1.1 percent. Labor input in cropping and other household occupation has no impact on pesticides use. The age and education of the household head do not matter either.

9.1.2 Hunan and Hubei Basin: Yiyang prefecture

The area along the middle reaches of the Yangtze River features mountains and hills within which two large plains are embedded: the basin of Hunan and Hubei and the Poyanghu Basin in Jiangxi. In these plains agriculture is carried out under similar conditions to those of the lower Yangtze basin: intensive, high yield agriculture dominated by rice paddies. Irrigation is a mixture of canals and pumps. Typical annual rotation is one to two rice harvests per year and, in addition, one winter crop such as rapeseed. The hills along the plain are often cov ered with forest.

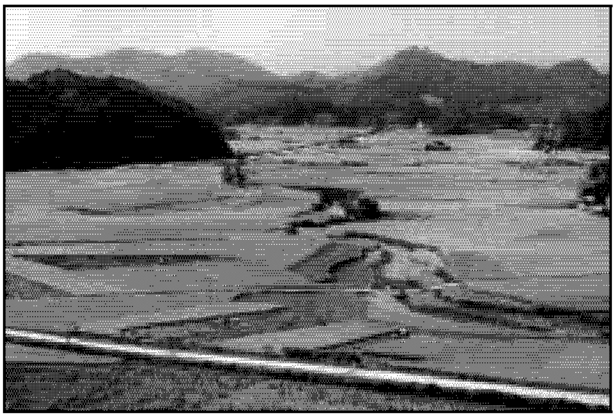


Figure 9-3: Agriculture in Yiyang

Source: Mueller 1997

The prefecture of Yiyang is located in Hubei province in the basin of Hunan and Hubei, between Changsha and Dongting Lake. The data set embraces 4507 households in four counties.

Agriculture in Yiyang is in line with the regional structure and very similar to those observed in Wuhu prefecture in Anhui: more than 99 percent of farmers use pesticides and on average they treat 88.4 percent of their sown area with pesticides. Labor intensive crops account for a large share of the sown area. Rice has a 76 percent share, 5.6 percent of sown area is rapeseed, 4.8 percent is vegetables, 4.6 percent is cotton and 1.9 percent is sweet potato. Average farm size is 0.41 hectares with an average of 1.9 harvests annually. This adds up to an average sown area of 0.79 hectare.

Table 9-2: Yiyang: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Rice	75.9%	97.2%	+	3.5%	3.0%	**[b]
Tuber (Sweet Potato)	1.9%	35.1%	?	-31.4%	-0.7%	0.0%[c]
Rapeseed	5.6%	25.5%	?	-7.7%	-0.5%	0.0%[c]
Cotton	4.6%	18.6%	+	8.2%	0.4%	8.2%[c]
Hemp	1.2%	11.8%	-	16.7%	0.2%	0.2%[c]
Vegetables	4.8%	94.9%	+	-3.3%	-0.2%	0.0%[c]
Other Crops	6.1%	21.4%	-	-33.6%	-2.3%	0.0%[c]
Total Sown Area (ha)	0.78		-	0	0	ns
Fertilizer	89.7%	99.0%	++	49.1%	49.8%	0.0%[d]
Film Cover	2.1%	35.6%	+	26.6%	0.6%	0.0%[d]
Ploughed by Tractor	47.1%	47.9%	+	0	0	ns
Labor Input Crop. (p/ha)	3.38		+	0	0	ns
Oth. Agric. Labor (p/ha)	0.16	7.9%	?	0	0	ns
Working in Industry (p/ha)	1.4	9.5%	+	0	0	ns
Oth Off Farm Labor (p/ha)	0.95	35.3%	+	0	0	ns
Household Head: Age	42.1		?	0	0	ns
HH: School Years	7.5		+	0	0	ns
Pesticides Use	88.4%	99.1%				
Adoption Ratio	1.1%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

The use of chemical fertilizer is high, as it is everywhere in the region: fertiliser is added on 90 percent of the sown area. 47 percent of the land is ploughed by tractor. Labor input in cropping is 3.39 persons per hectare, which tallies with the national average. In addition to agricultural labor, most of which work in cropping, about 41 percent of total household labor work outside agriculture, 25 percent work in industry. The most important animals are poultry (14.2/ha) and pigs (2.37/ha). Permanent crops account for only a small share of land.

The estimated results are in line with the imputed hypothesis. Since 99 percent of farmers use pesticides, adoption ratio is only 1.1 percent. The growing of rice has a significantly positive impact on pesticide use. This is hardly surprising given that rice is grown during the warm season of the year on the best land where irrigation is possible. The only crops that need more pesticides than rice are cotton and hemp. Vegetables need less pesticides than rice and cotton but more than all other dry land crops. The doubling of the vegetable area on land of sweet potato, rapeseed and other crops would increase pesticide use by only 1.1 percent. Farm size is of no significance.

Fertilizing has the most important effect on pesticide use. If fertilizer application increased to 100 percent, pesticide use would increase by 5.7 percent. The use of film cover, restricted as it is, also has a positive impact on pesticides use. Tripling the film cover would increase pesticide use by 1.3 percent. Ploughing with tractors has no impact. All labor related variables such as labor occupied in cropping, and off farm working, have no significant impact, either.

9.1.3 Sichuan Basin: West Chongqing

The Sichuan basin is an alluvial plain surrounded by hills and mountains. A thick layer of fertile, loamy soil and an intricate system of irrigation canals make it the most productive agricultural area in the region.

The climate is humid throughout the year, with mild winters. Landscape consists of both narrow plains and small hills. In the hill lands of the Sichuan Basin the gentle slopes are terraced from top to bottom. Irrigation is typically river and canal fed, the consequence being that wet fields are to be found in the lower parts of the hills and in the plains. On the higher parts of the hills dry field terraces are common. Double cropping is prevalent, under favorable conditions up to three harvests per year are possible. On wet fields, summer rice and winter wheat are put into rotation. On dry fields, winter wheat/sweet potato or winter wheat/corn is a common pattern. Other important crops are rapeseed, tobacco, tea, citrus fruit, cane sugar, tung oil and oil from the Chinese tallow tree.

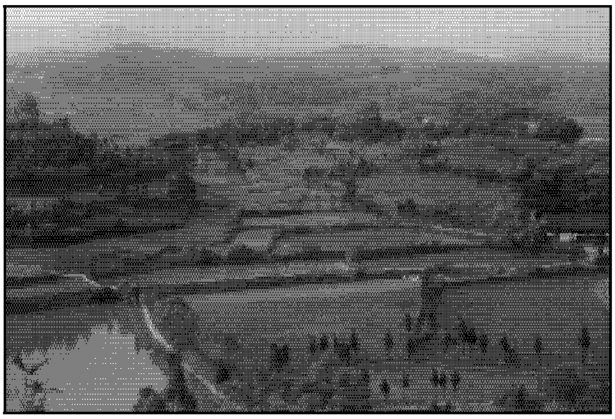


Figure 9-4: Agriculture in Dazu

Source: Mueller 1997

The counties of Dazu, Tongnan, and Tongliang are located about 160 km northwest from Chongqing in the southeastern part of the Sichuan basin. 5956 sample households were used for the analysis.

99.2 percent of farmers use pesticides, treating 72.4 percent of their sown area. Diverse agricultural conditions caused by the relief have given rise to a cropping mix that is more diverse than in other regions. With 40 percent of the sown area, rice is the main crop in the area, but other important crops are wheat (18%), sweet potato (17%), corn (9%), vegetables (5%) and rapeseed (3%). Farm size is extremely small in this area: average farm size is 0.29 hectare with an average of 1.65 harvests annually. This amounts to an average sown area of 0.47 hectares per farm. This is less than half of the national average.

In line with the fact that this region is well developed and highly fertile, chemical fertilizer usage is high. Fertiliser is added on 90 percent of the sown area, and 100 percent of farms apply chemical fertilizer. Machines are not used in this region. Corresponding to the small farm size, labor input in cropping is almost double the national average: on average 5.75 persons per hectare work in cropping. 67 percent of household labor is occupied with cropping and around 32 percent of labor force work outside agriculture. Very few permanent crops can be found in this region. Only some mulberry plantations (0.14 ha/ha SA) exist. Pigs and poultry are kept on the majority of farms.

The estimated results are in line with the imputed hypothesis. The adoption ratio of 0.4 percent corresponds to the fact that more than 99 percent of farms use pesticides. Besides the extraordinarily positive effect of rice, pesticide use on typical cash crops such as peanuts is also high, pesticide use on vegetables is higher than on cereal crops such as wheat, corn, or other cereals. If the vegetable area tripled at the expense of the existing area of sweet potato, pesticide use would increase by 4.6 percent. Since wheat is typically the winter crop in alternation with rice, it is grown on more fertile land than other summer crops, and therefore a higher pesticide use on wheat is more likely. Farm size has a zero impact.

The use of fertilizer has a substantially positive impact on pesticide use. An increase in the use of fertilizer to 100 percent of the sown area would increase pesticide use by 5.3 percent of the sown area. Labor related variables such as labor force occupied in cropping, off farm income or age and education of the household head have no significant impact.

Table 9-3: Dazu, Tongnan, and Tongliang: Factors Determining Pesticides Use*

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Rice	40.0%	98.9%	+	15.3%	8.5%	**[b]
Wheat	18.2%	97.7%	?	1.2%	0.3%	1.5%[c]
Corn	9.2%	80.2%	?	-1.5%	-0.2%	0.1%[c]
Other Grain: Barley, Sorghum, Millet, Oats	2.5%	47.0%	-	-11.3%	-0.4%	0.1%[c]
Tuber (Sweet Potato)	16.9%	98.0%	?	-31.9%	-7.5%	0.0%[c]
Rapeseed	3.3%	69.4%	?	-17.6%	-0.8%	0.1%[c]
Peanuts	1.1%	21.4%	?	23.6%	0.3%	59.1%[c]
Vegetables	4.9%	96.7%	+	2.0%	0.1%	2.1%[c]
Other Crops	3.6%	68.2%	-	-10.3%	-0.5%	0.3%[c]
Total Sown Area (ha)	0.47		-	0	0	ns
Fertilizer	90.5%	99.5%	++	55.3%	69.2%	0.0%[d]
Film Cover	0.6%	4.7%	+	17.7%	0.1%	0.0%[d]
Labor Input Crop. (p/ha)	5.75		+	0	0	ns
Other Agric. Labor (p/ha)	0.08	2.7%	?	0	0	ns
Working in Industry (p/ha)	1.74	8.2%	+	0	0	ns
Oth Off Farm Labor (p/ha)	1.00	27.6%	+	0	0	ns
Household Head: Age	44.2		?	0	0	ns
HH: School Years	6.47		+	0	0	ns
Pesticides Use	72.4%	99.2%				
Adoption Ratio	0.4%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

9.1.4 South China: Maoming prefecture

Hills and mountains dominate the southern part of China. They cover 90 percent of the land area and form a rugged surface drained by numerous rivers that flow into the South China Sea. Flatlands are only found along the sea coast and along the lower reaches of the Pearl River (Zhu Jiang). The Pearl River Delta is one of the most productive but also most populated areas of China.

Three grain crops per year can be grown, with a typical rotation cycle of rice/rice/winter wheat or rapeseed. In some places it is even possible to harvest three rice crops per year. Eight to ten rounds of vegetables can be grown and tea can be picked 3 to 4 times a year. Overall agricultural production is extremely intensive with high labor input and yields comparable to those of the Yangtze River valley. Most of the land is irrigated.

Figure 9-5: Agriculture in Maoming

Source: MMSTINET[1] 2002

The prefecture of Maoming is situated in the southwest of Guangdong province, on the shore of South China Sea. The data sample includes 8098 households in five counties.

In Maoming 98 percent of farmers use pesticides and on average they treat 81 percent of their sown area. Rice is the main crop (61%); other crops of importance are sweet potatoes (11.3%), vegetables (10.7%), peanuts (7.2%) and corn (2.8%). Average farm size is 0.25 hectare, and the land is harvested 2.3 times a year. This is the equivalent of an average sown area of 0.56 hectare per farm. As with pesticides, fertilizer input is high in the area: 87 percent of the sown area is fertilized. The only mechanical soil treatment is ploughing (8%).

With 5 persons per hectare working in cropping, labor input is tremendous. 39 percent of household labor are employed in cropping, 47 percent work in industry. Orchard production is substantial, with perennial crops amounting to 0.16 hectare of orchards per hectare of the sown area. The most important animals are poultry (105/ha) and pigs (5.5/ha).

The estimated results are generally in line with the imputed hypothesis. The low adoption ratio of 3.5 percent corresponds to the high adoption of over 98 percent of all farmers. Crop effects are in line with findings in other regions: besides rice, typical cash crops such as vegetables, sugar cane and tobacco have a positive impact. Most other crops are neutral or have a negative impact. Increasing cash crops such as vegetables, sugar cane and tobacco from 12 percent of the sown area to 20 percent would increase pesticide use by 2.4 percent if this were at the expense of the sweet potato area, or would decline by 0.3 percent if the expansion replaced rice. Farm size does not influence pesticide use.

The most dominant effect is, once more, the effect of fertilizer usage. An expansion of fertilizing from 87 percent to 100 percent of the sown area would increase pesticide use by 10.3 percent. Tractor usage has a positive but minor impact. Expansion of tractor usage from 7.8 to 50 percent would increase pesticide use by 0.9 percent. Labor input makes a significantly positive contribution to pesticide use, though a very small one.

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1 Maoming Sci & Tech Information Network Center (www.maoming.sti.gd.cn)

Table 9-4: Maoming: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Rice	61.3%	95.9%	+	5.6%	4.3%	**[b]
Corn	2.8%	19.0%	?	-10.3%	-0.4%	0.0%[c]
Tuber (Sweet Potato)	11.3%	82.1%	?	-22.8%	-3.2%	0.0%[c]
Peanuts	7.2%	64.1%	?	-1.4%	-0.1%	0.1%[c]
Tobacco	0.7%	6.4%	+	4.3%	0.0%	82.1%[c]
Sugar (Cane)	0.9%	5.4%	+	8.5%	0.1%	21.8%[c]
Vegetables	10.7%	83.9%	+	1.6%	0.2%	0.1%[c]
Other Crops	4.4%	35.7%	-	-18.1%	-1.0%	0.0%[c]
Total Sown Area (ha)	0.56		-	0	0	ns
Fertilizer	86.8%	98.5%	++	63.6%	68.2%	0.0%[d]
Ploughed by Tractor	7.8%	11.4%	+	1.7%	0.2%	1.9%[d]
Labor Input Crop. (p/ha)	5.07		+	0.1%	0.5%	1.1%[d]
Oth. Agric. Labor (p/ha)	0.21	6.3%	?	0	0	ns
Working in Industry (p/ha)	6.12	24.3%	+	0	0	ns
Oth Off Farm Labor (p/ha)	1.63	41.7%	+	0	0	ns
Household Head: Age	49.3		?	0	0	ns
HH: School Years	6.76		+	0	0	ns
Pesticides Use	81.1%	98.0%				
Adoption Ratio	3.5%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

9.1.5 North China Plain: Jining prefecture

This region consists of the floodplains of the Yellow (Huang), Hai, and Huai Rivers. It is the largest plain in the country and consists of hundreds of square kilometers of intensively cultivated and evenly fertile land, with no marginal land. Consequently, there are almost no forests in the plain. There are only tows of trees planted around the fields to protect the land from wind erosion. The climate is warm-temperate, with cold winters and extremely hot summers. Although rainfall is not low, there is a high degree of variability which leads to water shortages in winter and spring.

The region has a long history of cultivation, and cropping intensity is quite high. Although the land has been cultivated for thousands of years, it is still as fertile as ever and shows no sign of exhaustion. Since the ground is permeable and porous with much seepage loss, paddy can only been found in the proximity of rivers and lakes.

Irrigation enables farmers to stabilize yields or to extend the growing season which is naturally limited by the short rainy season. Today, over half of the cultivated land is irrigated, with groundwater constituting the main source of water. Dry weather, combined with increasing amounts of water being used for industrial and domestic purposes in urban areas, has led to shortages of both ground and surface water in recent years. Since rainfall is concentrated in three months in summer, land lying in depressions is often flooded. There is also a considerable amount of saline land in the depressions and along the sea coast.

This great plain is favorable for the cultivation of wheat and barley in winter and cotton, maize, millet, gaoliang, and peanuts in summer. The main crops are wheat, maize and cotton and production of these crops is the highest in the country. The area under peanuts, sesame and tobacco also rank highest among the regions while the area under millet, sorghum and soybean takes second place. The predominant cropping system involves two crops per year in irrigated areas or three crops every two years in dry farming areas. A uniform rotation is widespread with winter wheat as the main crop: the pattern is usually wheat/corn, sometimes wheat/millet, or wheat/soybean. This region is the leading producer of temperate fruits such as apples, pears, persimmons and jujubes (Chinese dates).

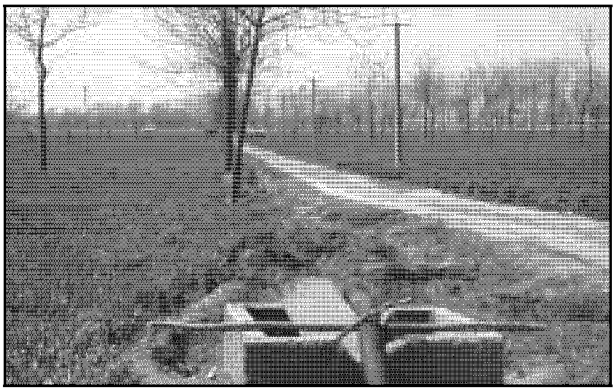

Figure 9-6: Agriculture in Qufu

Source: Mueller 1997

The three counties of Qufu, Yanzhou, and Zouchen were chosen for analysis. They are located in the prefecture of Jining which is in the south of Shandong province, south of Huang River and north of Nanyang Lake. The data set of these three counties comprises 4067 households.

Almost 98.5 percent of farmers use pesticides. On average 93.5 percent of the sown area is treated with pesticides. In line with the typical cropping pattern in the region wheat (42%) and corn (39%) make up 81 percent of total sown area. Other important crops are potato (7.7%), peanuts (6.9%), vegetables (3.3%) and soybeans (1.2%). Average farm size is 0.4 ha, with an average of 1.84 harvests annually. This makes an average sown area of 0.74 ha per farm. Use of chemical fertilizer is high: fertilizer is added on 97.3 percent of the sown area. Mechanical soil treatment is widespread, including not only ploughing with tractor (81%) but also mechanical sowing (31.1%), and harvesting (26.9%). Labor input in cropping is 3.3 persons per hectare. In addition to agricultural labor, most of whom are engaged in cropping, 43 percent of total household labor work outside agriculture, mostly in industry (28%). As regards of permanent crops, mulberry production is of significant importance in the region (0.33 ha/ha SA). The most important animals are poultry (25.4/ha), pigs (2.4/ha), and goats (2/ha).

The estimated results are in line with the imputed hypothesis: given the high level of pesticide use, the potential effects are very small. Although 98.5 of farms use pesticides, the adoption ratio is at a considerably high level of 16.3 percent. The results identify three categories of crops. The first category is corn which needs more pesticides than any other crop. This can be explained by the fact that corn is grown during the warm and wet season, the season in which pest outbreaks are higher than in any other season. The second category is wheat, potato, and vegetables which have a slightly negative impact on pesticide use. The third category has a negative impact on pesticide use: this is the case with soybean and peanuts. The negative effect of vegetables can be explained by the fact that they are only a marginal crop. The results of their impact are probably distorted by reasons not represented in the data set.[2] Farm size is not significant. The use of fertilizer has a strongly positive effect on pesticide use. Since the usage level is already very high, a further significant increase is not possible. The use of machinery and film covering has no impact on pesticide use. All labor related variables such as labor occupied in cropping and off farm working have no significant impact.

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[2] E.g. subsidized pesticides for wheat and corn, generally smaller pesticides use of vegetables farmers due to less pest pressure caused by a more balanced rotation.

Table 9-5: Qufu, Yanzhou, and Zouchen: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Elastic-ity	Marg. Effect	Signifi-cance
Wheat	41.7%	94.5%	?	-2.0%	-4.5%	**[b]
Corn	39.2%	93.9%	?	3.9%	9.2%	2.8%[c]
Legume (Soybean)	1.2%	13.7%	?	-0.2%	-13.5%	0.0%[c]
Tuber (Irish Potato)	7.7%	38.3%	?	-0.5%	-6.2%	92.1%[c]
Peanuts	6.9%	41.0%	?	-1.0%	-14.2%	3.0%[c]
Vegetables	3.3%	35.6%	+	-0.1%	-3.2%	0.1%[c]
Total Sown Area (ha)	0.74		-	0.9%	1.1%	10.4%[d]
Fertilizer	97.3%	99.5%	++	31.3%	30.1%	0.0%[d]
Film Cover	2.1%	11.2%	+	0	0	ns
Ploughed by Tractor	80.9%	83.3%	+	0	0	ns
Mech. Sown	31.1%	57.2%	+	0	0	ns
Mech. Harvested	26.9%	50.9%	+	0	0	ns
Labor Input Crop. (p/ha)	3.30		+	0	0	ns
Other Agric. Labor (p/ha)	0.05	2.4%	?	0	0	ns
Working in Industry (p/ha)	1.65	12.3%	+	0	0	ns
Oth Off Farm Labor (p/ha)	0.91	39.1%	+	0	0	ns
Household Head: Age	43.5		?	0	0	ns
HH: School Years	7.63		+	0	0	ns
Pesticides Use	93.5%	98.5%				
Adoption Ratio	17.2%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

9.1.6 Loess Plateau: Xifeng prefecture

The Loess Plateau is an area of plains and hills situated at an altitude of 1000 to 1500 meters above sea level. The region includes Shanxi, Shaanxi, Ninxia, western Henan and Eastern Gansu province. The plateau is covered with loessial deposits, a loose, friable soil material with a well-developed vertical structure of varying thickness stretching to 200m. Loess is extremely susceptible to water. As a result, countless gullies and ravines incise the plateau, giving it the appearance of a patchwork of millions of blocks of stone. This kind of landscape makes cultivation and transport very difficult and leads to an extreme shortage of water throughout the plateau. The climate in the region is mild and temperate with abundant but variable rainfall which often falls in the form of storms. As a result, droughts are not uncommon, especially in spring. The further north the cooler it is, the further west the dryer.

There is a long history of crop growing in the region. Most of the land lies on slopes and the plots are very small. On the slopes, almost all the arable land is on terraces due to the erosion problem. Even small slopes need to be terraced because of the low solidity of the soil. However, loess is solid enough for terraces to be made out of it. Terraces are built along the contour lines.

"Grain" crops (cereals, potatoes, legumes) are grown on more than 90 percent of the total area sown. Of these, 30 to 50 percent is wheat and 25 to 30 percent is maize. One harvest a year or three harvests every two years are possible. In east Gansu the typical rotation is winter wheat/millet/corn or winter wheat/gaoliang; in central Gansu, where the climate is too dry and too cold for winter wheat, the typical rotation is spring wheat/oats/linseed or potato/fallow. About one quarter of the cultivated area is irrigated but there are no rice paddies in this region.

Figure 9-7: Loess Plateau Agriculture

Source: Mueller 1997

The prefecture of Xifeng is located at the eastern tip of Gansu province. This area is the source of the Jing River. The data sample embraces 4187 households in eight counties.

In line with the low productivity of agriculture, pesticide usage is low: only 75 percent of farmers use pesticides at all. On average they treat 28.1 percent of the total sown area. Wheat is the main cereal crop (50% of sown area). Other important crops include millet or oats (15.4%), corn (7.4%), linseed (8.1%), tobacco (4.3%) and soybeans (4%). Average farm size is two hectares, with an average of 1.1 harvests annually. This amounts to an average sown area of 2.1 ha per farm.

Table 9-6: Xifeng: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Wheat	49.7%	99.3%	?	4.2%	7.4%	**[b]
Corn	7.4%	77.3%	?	-3.5%	-0.9%	22.8%[c]
Other Grain Barley, Sorghum, Millet, Oats	15.4%	69.5%	-	-10.0%	-5.5%	0.0%[c]
Legume (Soybean)	4.0%	31.3%	?	5.8%	0.8%	80.9%[c]
Tuber (Irish Potato)	2.6%	53.1%	?	22.0%	2.0%	17.7%[c]
Other oil (linseed)	8.1%	44.2%	-	-26.6%	-7.7%	0.0%[c]
Tobacco	4.3%	34.6%	+	20.9%	3.2%	1.5%[c]
Vegetables	2.1%	60.6%	+	39.5%	3.0%	0.1%[c]
Other Crops	4.7%	40.3%	-	-15.6%	-2.6%	0.1%[c]
Total Sown Area (ha)	2.14		-	0	0	ns
Fertilizer	64.6%	97.9%	++	16.6%	38.2%	0.0%[d]
Film Cover	10.3%	75.6%	+	38.2%	14.0%	0.0%[d]
Ploughed by Tractor	24.2%	52.8%	+	12.1%	10.4%	0.0%[d]
Mech. Sown	23.7%	61.7%	+	6.8%	5.7%	0.0%[d]
Mech. Harvested	2.6%	8.6%	+	10.8%	1.0%	0.0%[d]
Labor Input Crop. (p/ha)	2.09		+	0.5%	4.1%	3.4%[d]
Other Agric. Labor (p/ha)	0.04	4.8%	?	0	0	ns
Working in Industry (p/ha)	0.22	3.4%	+	0	0	ns
Oth Off Farm Labor (p/ha)	0.20	18.3%	+	0	0	ns
Household Head: Age	41.1		?	0	0	ns
HH: School Years	6.19		+	0.3%	5.8%	0.5%[d]
Pesticides Use	28.1%	75.1%				
Adoption Ratio	33.9%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

Fertiliser is added on 64.6 percent of the sown area; all the same, it is 98 percent of farms that apply chemical fertilizer. Mechanical soil treatment is widespread but, due to the terracing, fields are small and mechanization is not easily possible. Ploughing with tractor takes place on 24 percent of the sown area and mechanical sowing on about the same extent with 23.7 percent. Labor input is 2.1 persons per ha sown area. In Xifeng more than 82 percent of household labor is occupied in cropping. Only 17 percent have an occupation outside agriculture. As regards of permanent crops, mulberry production is of significant importance in the region (0.86 hectare per hectare sown area). Most farms have a few animals such as cattle (0.42/ha), donkeys (0.29/ha), goats (1.05/ha), sheep (0.53/ha), pigs (0.38/ha), or poultry (2.12/ha).

Since pesticides usage in Xifeng is low and differences between farms are higher than in other regions, the adoption ratio is about one third. The effects of cropping mix can be grouped into three categories: typical labor intensive cash crops such as Irish potato, tobacco, and vegetables have a positive effect, main staple food crops such as wheat, corn, and soybean have a slightly negative to slightly positive effect, and crops that grow better under marginal conditions such as linseed and sorghum, oats, and millet have a negative effect. If the area of vegetables and tobacco doubled, pesticide use would increase by 6 percent. Farm size is of no significance.

Any capital input usage has a strongly positive impact on pesticide usage. Lack of capital might be a central reason why pesticides are used to such a low extent in this region. The use of yield increasing inputs such as fertilizer and plastic cover have a substantially positive impact on pesticide use. If fertilizing increased from 64.6 to 80 percent, pesticide use would increase by 9 percent. An increase of film cover from 10 percent to 20 percent would raise the use of pesticides by 14 percent. Machinery usage also has a positive impact on pesticide use. Labor input has a slightly positive impact. Off farm activities and the characteristics of the household head only have a very minor impact.

9.1.7 Xinjiang: Turpan prefecture

Xinjiang province consists of vast lowland of dry deserts which are surrounded by mountain ranges which stretch up 5000 to 6000 meters above sea level. The lower areas have hot summers and cold winters with no particular seasonality of precipitation. Most of the available water comes from the mountains.

Traditionally agriculture was confined to oases lying on the alluvial plains below the mountains. Here the climate is so dry that irrigation is absolutely essential for agriculture. Mountain areas are mainly used for herding by nomads. Irrigation was already well developed centuries ago but the amount of irrigated land had been substantially expanded since 1949. While old oases are usually located along the lower reaches of rivers where soil conditions are more favorable, new cultivated land is often located along the upper and middle reaches of the river systems where it is easier to draw water. In the 1990s the ecological and economic limits of land reclamation were reached. Today 90 percent of the water coming from the mountains is used for agriculture. The river flow is extremely uneven and especially short in spring, which has necessitated the building of reservoirs. The lower reaches of the rivers as well as the lakes into which these rivers used to flow have dried up in recent years. The pumping of groundwater became a growing source of irrigation during the 1990s, and by the late 1990's about 20 percent of the water used in agriculture was groundwater.

Most of the cropland is harvested once a year. On places where winter wheat is planted three crops in two years are common. The main crops are wheat, corn, melons, sugar beet, cotton, and sunflowers. Some oases have specialized in particular cash crops. The traditional staple food is bread made from wheat.

Figure 9-8: Agriculture in Turpan

Source: Mueller 1997

Turpan is located in Xinjiang province southwest of Ürümqi and south of the Tiashan mountain range. Like most oases in Xinjiang, Turpan mainly consists of dry desert land without any vegetation. Annual rainfall is only 16 millimeter rain per year, comparable to rainfall in the Sahara. 100 percent of the water comes from the Tiashan mountains. A canal system diverts groundwater from the mountains range. The data set embraces 579 households in three counties.

In Turpan 76 percent of farmers use pesticides and on average 45.7 percent of the total sown area is treated. With 46 percent of the sown area, cotton is the main crop in Turpan. Further important crops are wheat (27%), other cereals (18.6%) and corn (8%). Vegetables only make up 2 percent of the total sown area. Average farm size is 0.95 hectares, with 1.4 harvests annually. This makes an average sown area of 1.27 hectare per farm.

Chemical fertilizing is very common: 84 percent of the sown area is fertilized, with 99 percent of farms applying chemical fertilizer. With 11 percent usage, film cover is a common measure to extend the vegetation period. Mechanical soil treatment is widespread: 94 percent of ploughing and 65 percent of sowing is done mechanically. Labor input in cropping is 4.1 persons per hectare. This figure also includes labor occupied in raisin production which is one of the main cash crops of the area. 87 percent of household labor engage in cropping. As regards of permanent crops, there is mulberry production (0.58 ha/ha Sown Area) and orchards (0.13 ha/ha sa). Sheep (11.3/ha) and goats (1.48/ha) are the most common animals in the region.

Table 9-7: Turpan: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypo-thesis	Marg. Effect	Elastic-ity	Signifi-cance
Wheat	27.2%	76.7%	?	-13.6%	-8.1%	0.0%[c]
Corn	6.0%	23.5%	?	-31.3%	-4.1%	0.0%[c]
Other Grain Barley, Sorghum, Millet, Oats	18.6%	53.7%	-	-37.1%	-15.1%	0.0%[c]
Cotton	46.2%	77.0%	+	26.2%	26.6%	**[b]
Vegetables, Mellon	2.0%	14.0%	+	17.0%	0.7%	54.8%[c]
Total Sown Area (ha)	1.27		-	0	0	ns
Fertilizer	84.6%	99.1%	++	31.5%	58.3%	0.0%[d]
Film Cover	11.5%	37.0%	+	35.7%	9.0%	0.0%[d]
Ploughed by Tractor	94.4%	95.5%	+	0	0	ns
Mech. Sown	65.2%	81.9%	+	8.6%	12.3%	9.1%[d]
Labor Input Crop. (p/ha)	4.13		+	0	0	ns
Oth Agric. Labor (p/ha)	0.05	2.6%	?	0	0	ns
Working in Industry (p/ha)	0.21	2.4%	+	0	0	ns
Oth Off Farm Labor (p/ha)	0.36	17.4%	+	0	0	ns
Household Head: Age	49.0		?	0	0	ns
HH: School Years	5.94		+	0	0	ns
Pesticides Use	45.7%	75.8%				
Adoption Ratio	32.5%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

The estimated results are in line with the imputed hypothesis, the adoption ratio is nearly one third (32.5%). Pesticide use is higher on typical cash crops with potential high returns such as cotton and vegetables, than on cereal crops such as wheat, corn, or other cereals. A further expansion of cash crops does not seem very likely since the production levels are already very high and water resources are short. Still, an expansion of vegetable production from 2 percent to 10 percent at the expense of cereal crops would increase pesticide use by 7.2 percent. Farm size does not matter.

The use of yield increasing inputs such as fertilizer and plastic cover have a substantially positive impact on pesticide use. The expansion of fertilizer to 100 percent would increase pesticide use by 10 percent. The expansion of film covering from 11.5 to 20 percent would raise pesticide use by 6.7 percent. While mechanical ploughing has no significant impact, mechanical sowing has a strongly positive impact on pesticide use. The expansion of mechanical sowing from 65 percent to 80 percent would increase the use of pesticides by 2.8 percent. Labor related variables such as labor force occupied in cropping, off farm income, or age and education of household head, have no significant impact.

9.1.8 North East China: Suihua prefecture

North East China, also called Manchuria, is composed of broad, alluvial lands which are surrounded by mountain ranges. The climate is tempered continental with bitterly cold winters and warm summers. A large share of the arable land is very fertile black soil. In the past it was forbidden for Han Chinese to move into the region. As a result the region remained scarcely populated. Since the 1950s, the government has promoted large-scale cultivation of land which was formerly lying waste. Many state farms have been established and millions of hectares of arable land have been reclaimed. Some 30 percent of the area currently being worked is cultivated as a result of these measures. Compared to other regions, there a much higher proportion of cultivated land available per capita of the agricultural population and there is land still waiting to be reclaimed.

Northeast China is characterized by single crop agriculture. The surface area which benefits from irrigation is much lower than in other regions. In general, little manure or fertilizer is applied, the standard of management is inferior and yields are relatively low. Since manure and fertilizers have only been used in very limited amounts, the organic content of the soils has suffered accordingly and the humus layer is diminishing. The crops cultivated in the region include maize, soybean, wheat, millet, sorghum, gaoliang, rapeseed, potatoes, linseed, sunflower, sugar beet, rice and vegetables. About a quarter of the country's overall corn production comes from this region, together with half of the country's soybean, 45 percent of its sorghum and millet, 92 percent of its linseed and 65 percent of the total area under sugar beet. Rice is mainly produced in the south of the region but through the improvement of irrigation and breeding of fast growing varieties, paddy rice has been extended northward. Most weed control is done by hoe, tractor or by using animals. Farmers sometimes uses herbicides on wheat and linseed.

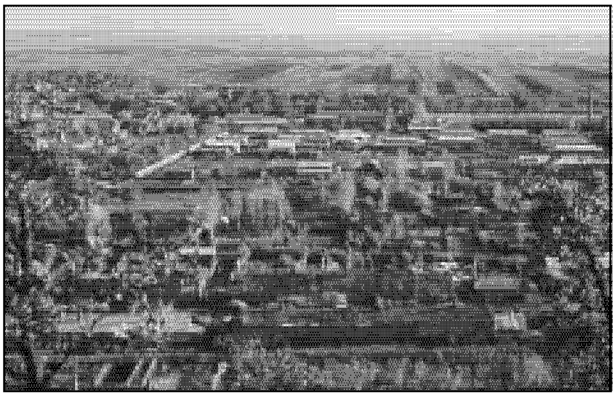

Figure 9-9: Agriculture in Heilongjiang

Source: Mueller 1997

The Suihua prefecture lies northwest of Harbin, the capital of Heilongjiang province, in a large alluvial plain which used to be marshland. Data of 1230 households in ten counties were analyzed.

Pesticide use is extremely low: only 29 percent of the sown are is treated with pesticides and only 48 percent of farms use pesticides at all. With 62 percent of the sown area, corn is the region's main crop. Other important crops are soybean (10%), wheat (6.7%), potatoes (4.3%), vegetables (4%) and sunflowers (2.6%). 6 percent of the cultivated area is wetland on which rice is cultivated. With an average farm size of 1.8 hectares, farm size is large compared with other regions of China. The average harvest is one crop per year.

Although there is only one harvest a year, fertilizer usage is high. Fertilizer is added on 85.6 percent of the sown area, and 96.4 percent of farms apply chemical fertilizer. Machine usage is high in the region: 66.6 percent of the sown area is ploughed with tractor. Mechanical sowing is common on 16 percent of the sown area. This is in line with the low labor input and large average farm size. Labor input in cropping is only 1. 5 persons per hectare. Compared to other regions in the country, off farm employment opportunities are low. Only 18 percent of the labor force work outside agriculture. As regards of permanent crops, mulberry trees are very common (0.9 ha/ha sa). The most important animals are poultry (32.2/ha) and pigs (1.13/ha).

Since pesticide usage is still very low in Suihua, there is still potential for considerable change. In line with the low share of farmers using pesticides at all, the adoption ratio is one third. Sowing rice, soybean, sugar beet, and vegetables positively affects pesticides use; wheat, corn and potato have a slightly negative impact; and sorghum/millet/other cereal and sunflower have a strongly negative impact. Increasing the vegetables area from 4.7 percent to 10 percent by replacing the corn area with crops with neutral to negative impact would increase pesticides use by 33.6 percent. Farm size has a very positive impact. This result is the opposite to what we would have expected from the imputed hypothesis. A possible reason for this is that capital endowment is much better on larger farms. Doubling the farm size would increase pesticide use by 27 percent.

The use of fertilizer has a substantially positive impact on pesticide use. Compared to other regions the effect is extremely low. An increase in fertilizing to 100 percent of the sown area would raise pesticide use by 3.7 percent. Film covering and mechanization do not seem to affect pesticide use significantly.

Except for animal husbandry (other agricultural activities), which positively affects pesticide usage, all other labor related variables have no effect at all. If employment in animal production doubled, pesticide use would increase by 3.6 percent.

Table 9-8: Suihua: Factors Determining Pesticides Use

	Mean	% > 0[a]	Hypothesis	Marg. Effect	Elasticity	Significance
Rice	5.9%	10%	+	43.4%	8.8%	0%[c]
Wheat	6.7%	23%	?	-7.1%	-1.6%	88%[c]
Corn	61.9%	86%	?	-8.1%	-17.2%	**[b]
Other Grain Barley, Sorghum, Millet, Oats	2.4%	13%	-	-20.9%	-1.7%	24%[c]
Legume (Soybean)	10.4%	41%	?	24.7%	8.8%	0%[c]
Tuber (Irish Potato)	4.3%	60%	?	-3.8%	-0.6%	71%[c]
Other Oil (Sunflowers)	2.6%	13%	-	-38.6%	-3.5%	0%[c]
Sugar (Beet)	1.0%	7%	+	20.2%	0.7%	10%[c]
Vegetables	4.7%	22%	+	39.1%	6.2%	0%[c]
Total Sown Area (ha)	1.85	100%	-	4.3%	27.0%	0%[d]
Fertilizer	85.6%	96%	++	7.5%	21.8%	3%[d]
Film Cover	2.3%	14%	+	0	0	ns
Ploughed by Tractor	66.6%	78%	+	0	0	ns
Mech. Sown	15.8%	34%	+	0	0	ns
Mech. Harvested	1.4%	4%	+	0	0	ns
Labor Input Crop. (p/ha)	1.51		+	0	0	ns
Other Agric. Labor (p/ha)	0.16	19%	?	6.8%	3.6%	0%[d]
Working in Industry (p/ha)	0.21	4%	+	0	0	ns
Oth Off Farm Labor (p/ha)	0.16	16%	+	0	0	ns
Household Head: Age	41.1		?	0	0	ns
HH: School Years	7.17		+	0	0	ns
Pesticides Use	29.3%	48%				
Adoption Ratio	33.0%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

9.2 Cross-Sectional Analysis of the Whole Country

The full data set available is a true one percent random sample of the agricultural household data of the National Agricultural Census i.e. it includes 1.91 million households that carry out cropping, in 2664 different counties. "Household data" means that it only contains the data of family farms. State, collective, and military farms are not included. However, it should be borne in mind that household farms cover 87 percent of the total sown area. This enormous extent of data record makes it possible to make an estimate which is really representative for family farming in China. The results refer quite truly to the very rough term "Chinese farmers" because all farmers in all regions of the country were taken into account. However, therein also lies the disadvantage of this approach, in that only general statements about the entire country can be made. Statements about the situation in actual geographical regions have limited validity. Individual variables like sugar, other grain, tuber, leguminous crops, or other oil bearing crops are aggregates of individual crops. The results are summarized in Table 9-9 on page 179.

Pesticide use is widespread in China: 70.4 percent of the sown area is treated with pesticides and only 7.9 percent of the sown area is on farms that use no pesticides at all. The three main crops are rice (24 %), wheat (24.2%), and corn (17.9%). Other common crops are rapeseed (4 %), peanuts (2.4%), cotton (2.8%), and tobacco (1.1%). Some crops that are aggregated are distinguishable in their categories: leguminous crops including soybean (4.3%), tuber crops including potato and sweet potato (5.7), other grain including barley, sorghum, millet, and oats (4%), other oil-bearing crops including sunflowers and linseed (1.2%), and vegetables (5.1%). Each farm cultivates an average of 0.66 hectare of cultivated area with an average of 1.77 harvests annually. This makes an average sown area of 1 hectare per farm.

Fertilizer usage is high in the country: fertilizer is added on 87.5 percent of the sown area, and 98.4 percent of farms apply fertilizer. Film covering is only used on three percent of the sown area. In line with the high labor input and small structures of the farms, use of machinery equipment is relatively low: 40 percent of the sown area is ploughed by tractor, 12 percent is sown mechanically and only 9 percent is harvested mechanically. This indicates that most farm work is still done manually. The figure for the labor force per hectare is 6.6, of which 3.4 (52%) work in cropping, 0.14 (2%) work in other agricultural activities such as animal husbandry or forestry, 2.34 (35.5%) are employed in industry and 0.67 (10.2%) have another off farm occupation.

On the whole, the results are in line with the imputed hypothesis: labor input, capital intensive agriculture (high fertilizer rates, machinery usage) and the cultivation of crops with the highest returns per hectare (e.g. rice, cotton, tobacco, sugar, and vegetables) all positively affect the use of pesticides. The adoption ratio is 29 percent: this means that 29 percent of all effects are caused by farmers' decision to use or not to use pesticdes at all. In detail this is as follows:

The sowing of rice, cotton, tobacco, sugar, and vegetables positively affects pesticide use; wheat, leguminous crops, rapeseed and peanuts have a slightly positive to slightly negative impact; and corn, sorghum/millet/other cereal and tuber crops, other oil-bearing crops, hemp and other crops have a strongly negative impact. Doubling the area sown with vegetables at the expense of corn and wheat would increase pesticideuse by 1.1 percent.

Farm size has a marginally positive impact: Large farms tend to use slightly more pesticides than small farms, although the amounts are not really of importance.

Fertilizer has the most substantial impact on pesticide use. An increase of fertilizer use from currently 88 percent to 100 percent would increase pesticide use by 7.4 percent. Other capital investment such as the use of film cover or machinery usage also affect pesticide use positively. The level of effect is, however, minor. Only a very strong change in their use would considerably affect pesticide use. Labor related variables have a slight but very minor effect: Labor input in cropping and off farm activities have a positive impact on pesticide use. Farms with older and better-educated household heads also tend to use more pesticides.

Table 9-9: Factors Determining Pesticide Use: Estimation Whole Country

	Mean	% > 0[a]	Hypo-thesis	Elastic-ity	Marg. Effect	Signifi-cance
Rice	24.0%	57.5%	+	4.8%	13.9%	**[b]
Wheat	24.2%	64.3%	?	1.3%	3.9%	0.0%[c]
Corn	17.9%	58.9%	?	-4.1%	-16.0%	0.0%[c]
Other Grain (Barley, Sorghum, Millet, Oats)	4.0%	14.9%	-	-0.4%	-7.1%	0.1%[c]
Legume (Mainly Soybean)	4.3%	31.9%	?	-0.1%	-1.9%	0.0%[c]
Tuber (Sweet+Irish Potato)	5.7%	50.5%	?	-2.2%	-27.3%	0.0%[c]
Rapeseed	4.0%	30.2%	?	0.2%	3.1%	0.0%[c]
Peanuts	2.4%	24.7%	-	-0.3%	-7.5%	4.8%[c]
Other Oil-Bearing Crops (Sunflower, Linseed)	1.2%	5.1%	?	-0.3%	-18.8%	0.0%[c]
Cotton	2.8%	14.7%	+	0.5%	13.7%	0.0%[c]
Hemp	0.2%	1.6%	-	0.0%	-9.3%	53.0%[c]
Tobacco	1.1%	5.1%	+	0.1%	7.7%	0.0%[c]
Sugar (Cane and Beet)	0.7%	2.9%	+	0.1%	11.1%	0.0%[c]
Vegetables, Mellon	5.1%	64.8%	+	0.8%	10.3%	0.0%[c]
Other Crops	2.4%	21.6%	-	-0.4%	-11.4%	0.0%[c]
Total Sown Area (ha)	1.00		-	0.4%	0.3%	0.0%[d]
Fertilizer	87.5%	98.6%	++	51.6%	41.5%	0.0%[d]
Film Cover	3.0%	16.0%	+	0.4%	10.4%	0.0%[d]
Ploughed by Tractor	40.4%	42.6%	+	2.6%	4.5%	0.0%[d]
Mech. Sown	12.0%	18.2%	+	0.3%	1.7%	0.0%[d]
Mech. Harvested	8.9%	16.9%	+	0.8%	6.2%	0.0%[d]
Labor Input in Cropping	3.43		+	1.0%	0.2%	0.0%[d]
Other Agric Labor (p/ha)	0.14	7.1%	?	0.0%	-0.2%	0.0%[d]
Working in Industry (p/ha)	2.34	15.6%	+	0.0%	0.0%	0.3%[d]
Oth Off Farm Labor (p/ha)	0.67	28.5%	+	0.1%	0.1%	0.0%[d]
Household Head: Age	43.6		?	0.2%	0.0%	2.1%[d]
HH: School Years	6.81		+	1.1%	0.1%	0.0%[d]
Pesticide Use	70.4%	92.1%				
Adoption Ratio	28.9%					

[a]% of farms with variable > 0; [b]omitted crop; [c]prob = omitted crop; [d]prob = 0; [ns]prob>10%, variable omitted. Detailed explanation Annex 2 Page 215.

9.3 Results by Variables

The eight case studies can be divided into three groups:

Yangtze Delta, Hunan and Hubei Basin, and South China and Sichuan Basin: Subtropical and tropical, humid climate, agronomic conditions allow the cultivation of rice on wet paddy fields on a considerable share of the land. High input use is rewarded with high yields. Most farmers apply pesticides on most of their land.

Table 9-10: Effect of Crops Choice on Pesticide Use

	Yangtze Delta: Wuhu	Hunan Basin: Yiyang	Sichuan Basin: Dazu	South Coast: Maoming	North Plain: Qufu	Loess Plateau: Xifeng	Xinjiang: Turpan	North East: Suihua	Whole China
Means									
Rice	65.7%	75.9%	40.0%	61.3%	--	--	--	5.9%	24.0%
Wheat	1.5%	--	18.2%	--	41.7%	49.7%	27.2%	6.7%	24.2%
Corn	--	--	9.2%	2.8%	39.2%	7.4%	6.0%	61.9%	17.9%
Oil[1]	20.1%	5.6%	4.4%	7.2%	8.0%	12.2%	--	13.0%	11.9%
Cash Crops[2]	8.9%	10.6%	4.9%	12.2%	3.3%	6.4%	48.2%	5.7%	9.9%
Other[3]	3.8%	7.9%	23.4%	16.4%	7.7%	24.3%	18.6%	6.7%	12.1%
Elasticity									
Rice	0.1%	3.0%	8.5%	4.3%	--	--	--	8.8%	4.8%
Wheat	0.3%	--	0.3%	--	-2.0%	7.4%	-8.1%	-1.6%	1.3%
Corn	--	--	-0.2%	-0.4%	3.9%	-0.9%	-4.1%	-17.2%	-4.1%
Oil[1]	-1.1%	-0.5%	-0.5%	-0.1%	-1.2%	-6.9%	--	5.3%	-0.5%
Cash Crops[2]	1.5%	0.5%	0.1%	0.3%	-0.1%	6.2%	27.3%	6.9%	1.5%
Other[3]	-0.8%	-3.0%	-8.4%	-4.2%	-0.5%	-6.1%	-15.1%	-2.3%	-3.0%

[1]soybean, rapeseed, peanuts, sunflower, linseed; [2]cotton, hemp, tobacco, sugar cane, sugar beet, vegetables, melon. [3]barley, sorghum, millet, oats, potato, other.

North China Plain: Favorable agronomic conditions with temperate climate. All crops are cultivated on dry fields, the main crops being wheat and corn. High yields with high input and corresponding high pesticide use is common.

Loess Plateau, Xinjiang and North East China: Temperate continental climate with cold winters and warm summers. In each region agriculture has particularly special sociological ecological conditions that lead to low pesticide use.

While all case study areas are located in the fertile surroundings of the particular regions, the whole country estimate also takes into account poor, remote and marginal regions. The large differences between the different regions which were all brought together in one single estimate may also counterbalance opposing effects. All the same, the results of both the case studies and the whole country estimate present a fairly consistent picture.

Table 9-10 illustrates the impact of crop choice on pesticide use in all nine case studies. As seen from the results above, crop choice has a significant effect on pesticide use.

Rice covers about a quarter of the total sown area in China: it is the predominant crop in tropical and subtropical China and has become a summer crop in the most fertile regions of the temperate climate. The findings of the model acknowledge what has already been stated elsewhere and what, indeed, was expected from the hypothesis: namely, that rice is grown on the best land with best water supply and the highest fertilizer input, which in turn leads to high pesticide use in all areas where rice is the dominant crop. Estimates demonstrate that more pesticides are applied on rice than on most other crops, i.e. the growing of rice affects pesticide use positively. This is seen most clearly in North East China, where rice is not the main crop and average pesticide use is low. The effect is moderate in rice dominated regions such as Yangtze Delta, Hunan Basin, and South China. Even the whole country estimate confirms that rice has the most positive effect of all crops. All this implies that any further expansion of the rice area will increase the use of pesticides. Any expansion will most likely take place in the temperate climate zone where new, fast-growing, cold-resistant varieties have been successfully introduced. A possible shrinking of the rice area, due to water scarcity or unfavorable market conditions for example, would cause a reduction in pesticide use.

Wheat, which covers another quarter of the total sown area of Chinese agriculture, is a common winter crop, rotated with rice in subtropical China and the major cereal crop together with corn in the temperate zone. The pesticide requirements of wheat are mixed and seem to depend strongly on local conditions: while, for instance, its effect is slightly higher than average in the rice-dominated Yangtze Delta, its effect is almost neutral in comparison with the strongly positive effect of rice in the Sichuan Basin. The strongly positive effect of wheat in the Loess Plateau is in line with the strong representation of cold and drought-tolerant crops. The comparably negative impact in North China can be attributed to the fact that wheat is often cultivated as a winter crop in these regions. In Xinjiang and North East China the negative impact is because of the strong presence of high yield crops such as cotton, vegetables and rice.

With 18 percent, corn is third behind rice and wheat. While it is cultivated in all regions, it is the main summer crop in North China and North East China. The effect on corn is ambiguous: while its overall effect is strongly negative, it varies from very positive in the North China Plain, neutral or only slightly negative in the Sichuan Basin and North East China, to strongly negative in South China and Xinjiang. This illustrates the high adaptability of corn: although high yields can be achieved under favorable climatic conditions using varieties that are responsive to fertilizer in combination with high input use, corn also grows under dry conditions where other cereals such as wheat would suffer.

12 percent of the sown areas is planted with oil-bearing crops such as rapeseed, soybean, peanuts, sunflower, and linseed. In the Yangtze Delta and Hunan Basin rapeseed is the winter crop of rice and its effect on pesticide use is negative. The effect is similar in South China coast and North China Plain where peanuts are the major oil crop. The negative effect in the Loess Plateau can be attributed to linseed which grows comparatively better under marginal conditions. The pesticide requirements of soybean in North East China are more or less as positive as those of rice or cash crops.

Cash crops comprise cotton, hemp, tobacco, sugar can, sugar beet, and vegetables. The market value of the yields of all these crops is typically higher than that of food crops: consequently they are mostly cultivated to be sold for cash. Being input and labor intensive crops, the postulated hypothesis would indicate that they consistently have a positive effect on pesticide use. Estimates confirm that this is indeed true for all these crops. Cotton has a thoroughly positive influence on pesticide use. Opening up the Chinese agricultural commodities markets will reduce the cotton area, which will therefore lead to a decrease in pesticide use. Compared with other crops grown on dry fields, the cultivation of vegetables has a strongly positive impact on pesticide use. Only cotton has a more positive impact. The expected expansion in the growing of vegetables, due to increasing domestic demand and the comparative advantage of Chinese agriculture, will cause pesticide treatment to increase.

Other crops include tuber crops as well as barley, sorghum, millet, and oats. Most of these crops grow best better under marginal conditions. For this reason, this category consistently shows a negative effect as far as pesticide use is concerned.

When examining the results for the impact of farm characteristics and the use of other inputs on the use of pesticides, it is striking that apart from fertilizer, which has a strongly positive effect, most variables – with a few exceptions – have no impact at all, or no significant impact, or only a very minor impact.

Fertilizer use most evidently has a very positive effect on pesticide use. The application of chemical fertilizer is high throughout China. While the application rate is only two thirds of the sown area in the Loess Plateau, it is more than 80 percent in all other regions. The use of plastic film to extend the vegetation period is most commonly applied in the Loess Plateau and Xinjiang. Its use there also very positively affects the use of pesticides. The use of machinery, too, consistently has a positive effect on pesticide use, as long as the effect of using machinery is significant. The strongest effect can be observed in the Loess Plateau and Xinjiang. All these results show that pesticide use is directly affected by the use of other capital inputs. Accordingly, the expected increase in capital input in Chinese agriculture will also cause pesticide use to increase. The biggest potential for expansion is in marginal regions where capital availability is a major constraint.

Table 9-11: Impact of Input Use and Farm Characteristics on Pesticide Use

	Yangtze Delta: Wuhu	Hunan Basin: Yiyang	Sichuan Basin: Dazu	South Coast: Maoming	North Plain: Qufu	Loess Plateau: Xifeng	Xinjiang: Turpan	North East: Suihua	Whole China
Means									
Fertilizer	93.6%	89.7%	90.5%	86.8%	97.3%	64.6%	84.6%	85.6%	87.5%
Film Cover	1.7%	2.1%	0.6%	--	2.1%	10.3%	11.5%	2.3%	3.0%
Machinery[1]	50.1%	47.1%	--	7.8%	138.8%	50.4%	159.6%	83.8%	61.3%
Labor	3.6	3.4	5.7	5.1	3.3	2.1	4.1	1.5	3.4
Off Farm Lb	52.2%	40.7%	31.9%	59.5%	43.2%	16.6%	12.0%	18.2%	45.8%
Age	42.5	42.1	44.2	49.3	43.5	41.1	49.0	41.1	43.6
Education	6.5	7.5	6.5	6.8	7.6	6.2	5.9	7.2	6.8
Farm Size	0.7	0.8	0.5	0.6	0.7	2.1	1.3	1.9	1.0
Elasticity									
Fertilizer	58.8%*	49.8%*	69.2%*	68.2%*	31.3%*	38.2%*	58.3%*	21.8%**	51.6%*
Film Cover	0.6%*	0.6%*	0.1%*	--	ns	14.0%*	9.0%*	ns	0.4%*
Machinery[1]	2.7%*	ns	--	0.2%**	ns	17.1%*	12.3%***	ns	3.7%*
Labor	1.1%***	ns	ns	0.5%**	ns	4.1%**	ns	ns	1.0%*
Off Farm Lb	1.3%***	ns	ns	ns	ns	ns	ns	3.6%*	1.1%
Age	ns	ns	ns	ns	ns	ns	ns	ns	0.2%**
Education	ns	ns	ns	ns	ns	5.8%*	ns	ns	1.1%*
Farm Size	2.1%**	ns	ns	ns	0.9%***	ns	ns	27%*	0.4%*

significance level: *: > 99% **: > 95% ***: > 90% ns: < 90%, variable omitted; --: variable not present [1]sum of mechanical ploughing, sowing, and harvesting;

Labor input in agriculture has no or only a minor effect on pesticide use. If the effect of labour input is significant, it is, however positive throughout China. The fact of household labor working outside agriculture, too, usually has no effect. From this it can be concluded that there is still a labor surplus is in Chinese agriculture, and hence working opportunities do not yet affect pesticide use. The education or age of the household head also hardly have any influence on pesticide use. Clearly, whether pesticides are used or not is not a question of age or education.

Table 9-12: Pesticide Use and Adoption Ratio

	Yangtze Delta: Wuhu	Hunan Basin: Yiyang	Sichuan Basin: Dazu	South Coast: Maoming	North Plain: Qufu	Loess Plateau: Xifeng	Xinjiang: Turpan	North East: Suihua	Whole China
Pesticide Use	88.2%	88.4%	72.4%	81.1%	93.5%	28.1%	45.7%	29.3%	70.4%
Pesticide Use %>0	99.1%	99.1%	99.2%	98.0%	98.5%	75.1%	75.8%	48.1%	92.1%
Adoption Ratio	1.3%	1.1%	0.4%	3.5%	17.2%	33.9%	32.5%	33.0%	28.9%

The hypothesis that larger enterprises use less pesticides is only confirmed by the results of the Yangtze Delta. In most case studies, farm size has no influence on pesticide use. Considering the fact that the structures of Chinese agriculture are small-scale and equally distributed, it is no surprise that farm size has no effect, or only a small effect, in most cases. In most areas the largest enterprises are still very small, so that hardly any economies of scale can be realized. The exceedingly positive effect in North East China and the slightly positive effect in North China indicate that in dry field agriculture on flatland, larger farms tend to use more pesticides. A possible reason is that that large enterprises are more likely to use labor saving techniques such as machines and pesticides.

The case studies results indicate that in regions where pesticide use is high, the effect of crop choice and technology mix on pesticide use is much smaller than in regions where pesticide use is low. This is mainly in poorer inland regions where economic and agricultural conditions are harsher i.e. Loess Plateau, Xinjiang, and North East.

The adoption ratio allows to distinguish the two sources of increase in pesticide use: on the one hand the adoption and, in cases where pesticides have already been adopted, the expansion of pesticide application. A high adoption ratio means that most of the change is caused by farmers adopting pesticides for the first time.

In the four rice dominated regions with subtropical and tropical climate, where pesticide use is above 70 percent and more than 98 percent of farms apply pesticides, the adoption ratio is negligible, below 4 percent, i.e. since almost all farmers already use pesticides there are hardly any new-adopters. Although the level of pesticide use is similarly high in North China, the adoption ratio of 17.2 percent is much higher than in the rice dominated regions. In Xinjiang, Loess Plateau and North East, where the levels of pesticide use are considerably lower, the adoption ratio is around one third. This indicates that in the dryland agriculture of the temperate climate zones, alternatives to pesticide use seem to be practised to a larger extent than in rice dominated regions, where pesticide use has become a core element of agricultural production. The comparably high adoption ratio in the results of the temperate regions and in the whole country results indicate that further economic development will increase the number of farmers that are using pesticides.

Summary

Economic Theory of Pesticide Use

In production theory, output or yield is a result of productive action of inputs within production function. Pesticides are, however, not yield-increasing inputs. Yet they indirectly increase the yield by reducing potential pest damage. To incorporate this characteristic within production theory, the concept of damage function is used. Here, the production function represents the potential yield that can be achieved through the use of productive inputs, while the damage function reduces this yield. The actual level of damage depends on the effect of pesticides and other measures to fight pests. Assuming a declining marginal effect as the quantity of pesticide input increases, the optimal level of pesticide input is where the marginal revenue of a unit change in pesticide use equals the pesticide price. This optimum level depends on the crop specific production function, the damage function, as well as the relationship between price of pesticides, cultivated crops and other inputs.

Pesticide Use and Trends in Chinese Agriculture

There are three key decisions each crop farm is confronted with that directly affect the use of pesticides: crop choice, corresponding productive inputs, and adequate pest management.

The mix of crops planted on the farm determines the set of pests that can potentially occur on that farm. If high value crops are cultivated, fighting pests is more profitable, justifying higher pest management costs and, consequently, higher pesticide use. Chinese statistics show that the highest returns and input expenditures can be found in rice and cash crops such as cotton, tobacco, peanuts, fruits, and vegetables. While economic development and the opening of the markets will lead to a further expansion in the production of these high value cash crops, the Chinese government continues to enforce the production of low value grain by means of procurement quotas and input subsidies.

The factor endowment and input mix determine the production potential of the cultivated crops. High use of productive inputs generally goes together with high pesticide use. Chinese agriculture is characterised by land shortage and a high population density. To feed the population, yields have to be ever higher, and this can only be achieved by higher input use. Ongoing economic development has led to an increase in off farm incomes. This encourages farmers to increase returns in crop production and reduce labor input by replacing it by capital inputs. All these trends point towards a further, rapid increase in the use of pesticides. Water scarcity in north China increases the costs of irrigation, which forces farmers either to turn to crops that consume less water, or to produce high value crops whose higher returns can compensate for the higher production costs. In the past, the introduction of improved seed went hand in hand with greater pesticide use, and the ongoing improvement of seed might continue this trend. But given that new varieties are also less susceptible to pests, declining pest pressure will also reduce pesticide needs. Although fertilizer usage levels are high even today, all trends point towards a further increase in the use of fertilizer. Since this will increase yields it is likely that the accretive use of fertilizer will stimulate expenditures for pest management.

The choice of which particular pest management measure to use against a particular pest depends on the price of the different measures that are available on a farm as well as the the farmer's knowledge of the effect of the different measures. Current conditions in the Chinese pesticides market promote the high use of pesticides. Many of them are outdated products that have been prohibited in industrial countries and are no longer traded internationally because they are toxic and persistent. In addition, the use of pesticides in grain production is actively encouraged by the government, which increases the use of pesticides in grain. Rising labor costs tend to increase the use of herbicides. Although there are no signs of a dramatic change in the short run, there is a long term trend towards integrated pest management, environmentally sounder pesticides of reliable quality and host plant resistant biotech crops.

Despite the fact that per hectare returns are already high in Chinese crop production, trends are pointing towards further enhancement of returns by changing from low value crops with low input use to high value crops and high input use. Higher returns will increase the value of a potential loss due to pests, and this will in turn justify a higher expenditure on pest management. Improved pest management practice and the enhanced host plant resistance of new seed might reduce the overall need to fight pests with pesticides.

Empirical Analysis: Hypothesis, Model and Data

Having found that the leading trend points towards an increase in both output value and use of input, it is now interesting to see whether the theoretical assumptions regarding pesticide use can be confirmed by empirical analysis. The key hypothesis is: high output value and high input costs positively affect pesticide use.

The chosen approach is a cross-sectional analysis. Relying on the one percent sample of the household data of the First Chinese Agricultural Census 1997, a doubly censored Tobit regression model is applied to find out what pesticide use depends on. In the model, pesticide use is related to crop variety, fertilizer use, machinery usage, plastic film cover, farm size, labor input, other economic activities of household labor, as well as age and education of the household head. The data only consist of area information such as "share of sown area treated with" or "cultivated with"; no information was available on quantities or prices.

Results by Region

In order to get a picture of the real conditions, the data samples of eight prefectures have been chosen and analyzed, one for each of the major agricultural regions of China: Yangtze Delta with Wuhu (Anhui), Hunan and Hubei Basin with Yiyang prefecture (Hunan), Sichuan Basin with Dazu, Tongnan, and Tongliang county (Chongqing), Sichuan Basin with Dazu prefecture (Chongqing), South China with Maoming prefecture (Guangdong), North China Plain with Jining prefecture (Shandong), Loess Plateau with Xifeng prefecture (Gansu), Xinjiang with Turpan prefecture, and Northeast China with Suihua prefecture (Heilongjiang).

1) The first sample is Wuhu prefecture in Anhui province. It lies in the alluvial plain of the Yangtze Delta, with a subtropical climate and abundant water. Most agricultural land is wetland. Typical rotation is two crops a year with rice/rice or rice/rapeseed. As a result, 66 percent of the sown area is rice and 20 percent rapeseed. Other crops are cotton (2 %) and vegetables (7%). With 3.6 persons per hectare working in cropping, 52 percent of household labor working outside agriculture, and an average sown area of 0.6 hectares per farm, cropping is very input intensive: 88 percent of the land is treated with pesticides, 93 percent receives chemical fertilizer, 50 percent is ploughed by tractor. The results show that vegetables need more and rapeseed less pesticide than rice. While larger farms use less pesticide, all yield-increasing inputs positively affect pesticide use.

2) Yiyang prefecture, part of the Hunan and Hubei Basin, has similar agricultural structures to Wuhu: with an average of 1.9 harvests per year, 1-2 rice harvest are typical, and the main crops are rice (76%), rapeseed (6%), vegetables (5%), and cotton (5%). The average sown area is 0.8 hectares, 3.4 members of the labor force work per hectare and 41 percent work outside agriculture, 88 percent of the sown area is treated with pesticides, 90 percent receives chemical fertilizer, and 47 percent is ploughed by tractor. The results show that labor intensive crops such as rice, cotton, and vegetables need more pesticides than all other crops. While fertilizer and film cover have a strongly positive effect, all other variables have no significant effect all.

3) The three sample counties of Dazu, Tongnan and Tongliang lie northwest of Chongqing in the central Sichuan Basin. With a humid climate of mild winters, the farmland is a mixture of plains and terraced slopes with canal-fed irrigation. Typical crop rotation is rice/wheat, the main crops being rice (40%), wheat (18%), sweet potatoes (17%), corn (9%), vegetables (5%), and rapeseed (3%). An average of 1.6 crops can be harvested annually. On an average sown area of only 0.5 hectares, 5.7 persons per hectare work in cropping, and 32 percent of household labor work outside agriculture. Mechanization is inexistent but use of pesticides (72%) and fertilizer (90%) is high. The results are in line with expec-

tations: both rice and wheat, which are cultivated on the best land, and vegetables and peanuts positively affect pesticide use. Corn, sweet potato and rapeseed need significantly less pesticide. Fertilizer and film cover have a strongly positive impact on pesticide use. Farm size and labor related variables have no impact as labor supply is abundant.

4) Maoming lies southwest of Guangdong on the coast of the South China Sea with its typical tropical humid climate. The main crops are rice (61%), sweet potato (11%), vegetables (11%), peanuts (7%), and corn (3%). The average sown area is 0.6 hectares and 2.3 crops are harvested annually. The area is very densely populated: 5 persons per hectare work in cropping and 60 percent of farm household labor work outside agriculture. Consequently, the level of mechanization is low and the use of pesticides (81%) and fertilizer (87%) is high. Under these circumstances rice and typical cash crops receive most pesticides. Fertilizer as well as labor and mechanization positively affect pesticide use.

5) Jining prefecture in Shandong province is part of the alluvial plain of the Yellow river with a warm temperate climate. Between the hot summers and cold winters, water shortages have to be bypassed with groundwater-fed irrigation. Typical rotation is corn/wheat with main crops being wheat (42%), corn (39%), potato (8%), peanuts (7%), and vegetables (3%). With an average sown area of 0.7 hectares, 1.8 harvest a year and 3.3 persons per hectare, cropping is capital intensive: 93 percent of the sown area is treated with pesticides, fertilizer is added on 97 percent of the sown area, and there is a high level of mechanization: ploughing 81 percent, sowing 31 percent and harvesting 27 percent. 43 percent of household labor work outside agriculture. While corn affects pesticide use positively, the cultivation of wheat, potato and vegetables is neutral; soybean and peanuts need less pesticide. Fertilizer use as well as farm size positively affect pesticide use. Machinery usage, however, showed no impact on pesticide use.

6) Xifeng prefecture is part of the Loess Plateau in Gansu province. Agriculture takes place on terraces in a mild and temperate climate with cold winters and variable, but abundant rainfall. With 1.1 harvests annually and an average sown area of 2.1 hectares, the main crops are wheat (50%) oats (18%) corn (7%), sunflowers (8%), tobacco (4%), and soybeans (4%). 2.1 persons per hectare work in cropping and only 17 percent of the farm labor force work outside agriculture. Treatment with pesticides is a mere 28 percent and even fertilizer application does not exceed 65 percent of the sown area. Mechanization is widespread but limited due to the relief of the land (24% ploughing and sowing). Results show that labor intensive crops such as Irish potato, tobacco and vegetables are more frequently treated with pesticides that staple crops such as wheat, corn, and soybean. Marginal crops such as oats and sunflowers need less pesticide. The strongly positive effect of fertilizer, film cover, and mechanization, as well

the significant effects of labor input and the education of the household head, indicates that there is a relationship between output value and pesticide use.

7) Turpan prefecture is an oasis in Xinjiang province, the northwestern desert region of China. Here hot summers alternate with cold winters and agriculture relies on irrigation water from the close mountain rages. Average farm size is 1.3 hectares of sown area, with 1.4 harvests per annum and 4.1 persons per hectare. 46 percent of the sown area is treated with pesticides, 84 percent receives fertilizer and mechanization is high (94% ploughing, 65% sowing). In addition to the two cash crops of cotton (46%) and vegetables (2%), the main staple crops are wheat (27%), corn (8%), and other cereals (19%). Only 10 percent of household labor work outside agriculture. The estimation show that vegetables and cotton, the crops allowing higher returns, are more often treated with pesticides. Fertilizer use, film covering as well as mechanical sowing also positively affect pesticide use.

8)Suihua prefecture lies Northwest of Harbin in Heilongjiang province in Northeast China in a large alluvial plain with fertile black soil. The climate is tempered continental with cold winters and warm summers. With 1.8 hectares of sown area per farm and one crop per year, 62 percent of the sown area is planted to corn, 10 percent to soybean, 7 percent to wheat, 4 percent to potato, 4 percent to vegetables, and 3 percent to sunflowers. 6 percent of the land is rice paddies. Only 1.5 persons work on a hectare and off farm working activity affects only 18 percent of the household labor force. While only 29 percent of the sown area is sprayed with pesticides, fertilizer use is 86 percent and machinery usage is widespread: 66 percent ploughing and 16 percent sowing. The results are in line with returns of the crops: rice and vegetables have a very positive impact on pesticide use, sugar beet and soybean have a slightly positive impact, the impact of wheat, corn, and Irish potato varies from neutral to slightly negative, and finally sunflowers and other cereals have a negative impact. Farm size, fertilizer use, as well as labor input positively affect pesticide use.

Results Whole Country Estimation

Finally, the whole data set was analyzed to get a broader view of Chinese agriculture. Since the full data set embraces a real 1 percent sample of all Chinese farmers, i.e. 1.9 million households, the results are truly representative.

In China as a whole, the sown area is allocated to following crops: rice (24%), wheat (24%), corn (18%), sweet and Irish potato (6%), vegetables (5%), other cereals (4%), leguminous crops /soybeans (4%), rapeseed (4%), cotton (3%), peanut (2%), and tobacco (1%). The average sown area is 1 hectare with 1.8 harvests annually. With 3.4 persons per hectare, 46 percent of household labor work outside agriculture. 70 percent of the sown area is treated with pesticides, 88 percent receives fertilizer, and mechanization is 40 percent for ploughing, 12 percent for sowing, and 9 percent harvesting.

On the whole, the results are similar to those of the 8 case studies: the cultivation of crops with the highest returns per hectare such as rice, cotton, tobacco, sugar, and vegetables, as well as input and capital intensive agriculture with high fertilizer and machinery usage, all positively affect the use of pesticides. Farm size and labor related variables have a slightly positive, but a minor impact.

Results by Variable

Despite the large differences between the regions, the results present a picture which is consistent with the hypothesis drawn from literature and theory.

Crops can be classified in three categories: high value crops that grow on the best land during the best growing season and that are treated most with pesticides; normal field crops with reasonable pesticide use; and, finally, low value crops that grow best in marginal locations and on which less pesticide is applied. Empirical results could confirm this hypothesis: rice paddy and typical cash crops such as vegetables, cotton, soybean, sugar cane, sugar beet, and tobacco have a substantially positive impact on pesticide use. The pesticide requirements of wheat and corn and depend on the local conditions. Sweet potato, linseed, barley, sorghum, millet and oat are mostly cultivated on marginal land; consequently these crops need less pesticides.

Several studies have shown that the use of capital inputs such as fertilizer, plastic film, or machinery substantially contribute to yield increase in Chinese agriculture. Higher yields increase the value of potential pest damage, and so they also positively affect pesticide use. Estimations confirm this hypothesis entirely. Fertilizer use has the clearest and the most positive effect on pesticide use. But the use of plastic film or mechanical equipment positively affects pesticide use, too.

Farm size, labor input and related variables had either no effect, or only a minor effect, on pesticide use. This result is in line with the fact that most farms are extremely small with a strong labor surplus.

All in all, this analysis confirmed that pesticides are applied most on those farms that cultivate crops with which the highest revenue per sown are can be achieved and that use the highest amount of capital inputs. Based on these results it can be concluded that if the Chinese economy continues to grow at such a rapid rate, and if the agricultural commodities markets really open up during the next few years, the farmers' propensity to use pesticides will accelerate.

Conclusion

1. Reforms of the Chinese Economy

When China started its reforms 20 years ago, the economy was a planned market system in which all economic activities were organized and controlled by central planning bodies. These reforms were not a decision taken all at once with an immediate and systematic conversion of the whole economy, but a series of piecemeal adjustments. Usually, reforms were first tested locally on a small scale; if they were successful, they were gradually extended and finally applied to the whole country. This frequently led to the situation of a so-called "dual economy", with part of the economy market-orientated and part under government control.

Starting with agricultural products, and extending later to industrial products too, parallel free markets were introduced which gradually replaced the planned system; restrictions on interprovincial and foreign trade were lowered. After agreements have been signed with many member countries, China will very likely become a full WTO member by 2004. This means that further steps on the road to liberalizing the domestic market and the foreign trade regime can be expected.

In line with the opening of the markets, the actors in those markets have gradually been released from production plans. This process began in agriculture, when rural households became the unit of agricultural production, and then spread to state and collectively-owned enterprises, including manufacturing industries and trade companies. As management received freedom in the realm of business decisions, the companies started to be responsible for becoming profitable. At the same time, more and more business areas were opened to private firms and, to a certain extent, also to foreign companies. Since markets are now the major factor driving resource allocation, the Chinese government has changed the name of the economic system to the "Socialist Market Economy".

The Chinese government still has a dominant role in the economy by dictating production decisions, intervening in product markets, and deciding on investments in the state sector. While reforms have helped to accelerate economic development, the government is hesitating about allowing the state sector to become market-driven. Many state companies would not be competitive in an open market environment, and several of them are loss-making and can only survive if they receive subsidies from the government. Liberalizing the state sector has the potential to make millions of workers redundant, which in turn would very likely lead to social unrest. In addition, the government is willing to keep control of parts of the economy they consider crucial for the country's independence.

2. Economic Growth and Changing Comparative Advantages of Chinese Agriculture

When family farms became the unit of production and food markets started to develop, farmers gradually adjusted their production mix towards demand needs and profit maximization, i.e. away from cereal production towards the production of meat, fruits and vegetables. Compared to other countries, China has relatively little arable land per capita. Consequently, the comparative advantages of Chinese agriculture lie in labor intensive crops such as fruits and vegetables. The further opening of foreign trade is likely to stimulate production of these labor intensive products.

The liberalization of the Chinese economy has caused a considerable spurt in economic growth and has led to a transformation of the structure of the Chinese economy. Growth has been much higher outside agriculture, mainly in the new private sector and in rural industries. As a consequence, they are offering new jobs to the millions of hitherto abundant agricultural workers. Higher incomes and a rising urban population have changed consumption patterns towards more meat and vegetables, which in turn has led to a further change in the production mix in agriculture.

Since labor costs have risen and farmers now have the opportunity to generate income outside agriculture, there is a strong trend towards using more manufactured inputs, i.e. fertilizer and pesticides. This not only helps to raise labor productivity, but can also replace work processes which were formerly done manually. Although input use is already at a relatively high level in some areas of China, there is still potential to raise yields in the long run. The shift towards labor intensive products will enhance gross margin per area sown and will make input use even more profitable.

3. Grain Bias

Ever since the founding of the People's Republic of China, the driving principle in Chinese agricultural policy has been to provide sufficient and cheap grain to urban consumers. All agricultural policy measures were, fundamentally, aimed at achieving this goal and were applied at different levels of the Chinese food market chain. Since 1978, the institutional framework of Peoples Communes and the Household Responsibility System have included grain production obligations. High investments in the infrastructure of the input industry, and in agricultural research into the industry, have helped to increase yields. In turn, grain has been purchased at low prices by the state grain monopoly and transferred to urban consumers who have been offered cheap grain but, due to lack of sufficient supply, only in rationed quantities. The Houko system, forbidding rural citizens to settle in urban areas, and the one child policy were also measures to limit the growth of the urban consumer population.

Despite the reforms of the rural institutions and of the food market, the government continues to lay great emphasis on self-sufficiency in grain, this being one of the main goals of agricultural policy. In 1996 the government reconfirmed its determination to keep China 95 percent self-sufficient in grain production i.e. in rice, wheat, maize, soybean, sorghum, millet, as well as root and tuber crops. It is for this reason that the government is unwilling to fully open the food sector to market forces.

a. Grain Market

Each farm is still obliged to sell a certain quota of grain to the state marketing system at a predetermined price. As land tenure contracts directly depend on the fulfillment of this quota, farmers are forced to produce a certain quantity of grain, which prevents them from fully adjusting their production towards profit maximization.

When agricultural markets were liberalized and the booming economy offered new employment opportunities for the rural population, farmers expected a higher income from agricultural production, too. Since labor productivity of small scale grain production is lower than that of other crops, farmers were unwilling to fulfill the grain quota at prices below market prices, with the result that the government found it difficult to enforce procurement quotas. In the late 1980s, therefore, the government raised quota prices to the market level and, in the late 1990s, it even started to buy grain at prices above market level. This ultimately helped to reinforce the state grain monopoly, but the process illustrates the trend: grain production leads to a fall in the comparative advantages in Chinese agriculture at a time when the economy is developing and markets are opening. During the last 20 years, China has turned from taxing grain production to subsidizing it.

In the mid 1990s, the Chinese government delegated the responsibility to achieve grain self-sufficiency to provincial governments. This meant that from now on each province had to become self-sufficient in grain production. It is therefore provincial governors who now dictate grain production quotas and enforce procurement, for example by blocking Interprovincial trade. In densely populated and well-off regions, grain self-sufficiency is achieved either at the cost of production of other crops or by enhancing yields through accelerated input use. Farmers, however, will only do this if grain prices are attractive.

b. Input self-sufficiency

An offshoot of the Chinese policy of being self-sufficient in grain is the aim of self-sufficiency, too, in the supply of agricultural inputs such as fertilizer and seed. Although fertilizer and seed companies are officially expected to operate like independent commercial enterprises, their business operation is very much under government control. State-owned companies have to deliver certain quotas at regulated prices which are sold to the state supply system. Often prices are so low that the companies cannot justify their investment. In some places, companies can only survive thanks to government subsidies.

Along with the introduction of the provincial responsibility system in the mid 1990s, provincial governors also became responsible for the supply of fertilizer and seed. They have the power, for example, to restrict interprovincial trade. Companies that try to expand their production at given prices find it difficult to sell their products in other provinces. Although foreign companies are welcome to improve the technological standard of the Chinese fertilizer and seed industry, they are discriminated against to the benefit of the domestic producers. As with the domestic companies, they have to secure market access to each province separately.

The incomplete commercialization of the inputs sector has led to the situation in which loss-making state-owned companies are offering inputs below production costs. Some business areas are exclusively reserved for state companies and the extremely fragmented and monopolistic market system makes it difficult for new market actors to enter the business.

4. Trends in the Seed and Pesticides Sector

a. Seed Market

Chinese agriculture produces high yields with a high level of input applications which can only unfold their potential through the use of fertilizer responsive seed. As China is one of the largest food producers in the world, the Chinese demand for these seeds is equally large.

There is a trend of production shift from staple food crops to high value, labor intensive crops, such as fruits and vegetables. Consequently, seed demand for these crops is likely to continue to rise as the economy continues to grow and as Chinese food markets open to the outside world. As the Chinese government will continue to enforce grain production, grain prices will remain at an attractive level which, in turn, will make it profitable for farmers to buy the best seed on the market.

The structural crisis of the Chinese seed system, coupled with declining public investment in the 1980s, has led to a slowdown of seed improvement in recent years and has widened the technological gap vis-à-vis the industrial countries. In consequence, any multinational company that can successfully enter the Chinese market will have a competitive edge, due to its technological advantage. In addition to the further increasing yields, there is also a large potential demand for seed varieties with pest and herbicide resistance as well as drought tolerance. Genetically modified seed varieties have widely been adopted by Chinese farmers. Export restriction to countries that are sensitive to genetically modified crops may alter this situation.

Current cultivation practices which involve the extensive application of toxic broad-band pesticides may destroy the characteristics of pest resistant varieties. For this reason, the introduction of such varieties only makes sense if farmers are taught their appropriate use.

The production and commercialization of hybrid seed of all the major food crops is reserved for state owned companies. Only non-hybrid seed, as well as seed of fruits, vegetables and other cash crops, can be commercialized by other market actors, and this goes for foreign companies too. However, the distribution channels are dominated by the state-owned distribution system which is known to favor domestic producers. A second way of entering the Chinese seed market is to found a Joint Venture with an existing state-owned seed company. This way, foreign companies can have access to the hybrid seed market and enter the domestic seed distribution channels under the name of a Chinese company.

For all this, Chinese legislation in the field of intellectual property rights is weak and hard to enforce. Since Chinese research institutes find it difficult to protect their innovations from being copied, it is questionable whether a foreign company can be any more successful. As described above, the Chinese seed market is fragmented into provinces. Securing access to any one province, therefore, does not necessarily mean that a certain seed can be sold throughout the country. Officially, grain seed prices are still subject to administrative control with fixed profit margins.

b. Pesticides Market

The characteristics of the pesticides market have some similarities with those of the seed market. China is one of the largest producers and consumers in the world for pesticides. But the Chinese pesticides industry is suffering a dramatic crisis. With small scale production units and outdated production equipment, they produce too many toxic broadband pesticides. As their research infrastructure is too limited and their financial capacity is weak, it is unlikely that they can change the situation in the short term. From this point of view, the Chinese pesticides market would seem to be extremely attractive for a foreign pesticides company, as they can offer what Chinese companies are not able to provide.

The varying quality of pesticides and the lack of educated extension staff have led to widespread overuse of pesticides in Chinese agriculture, with the corresponding increase in pesticide-resistant pests. Introducing new, specialized pesticides under these circumstances would destroy the effectiveness of the product after a short period. Since awareness of environmental factors and of health factors in food products is gaining importance in China, several pesticides currently on the market can be expected to be banned in the very near future. There are also attempts to improve the extension system and promote Integrated Pest Management. Consequently, the market potential for low-toxic and pest-specific pesticides is likely to rise substantially in the long run.

Currently, pesticides imports are under government control and are restricted by a certain import quota. Products that have finally been imported enter a state distribution system in which they can be discriminated against to the benefit of domestic brands. It will be interesting to see whether China's accession to the WTO will bring an improvement in market access, i.e. higher import quotas and access to alternative distribution channels.

Foreign companies can also enter the Chinese market by founding a Joint Venture with an existing Chinese state-owned pesticides company. This may help them to gain access to the Chinese distribution system. Joint Ventures are, however, restricted to new pesticides that are not yet produced by a Chinese company. In the case of pesticides too, the protection of intellectual property rights is weak.

The Chinese market consists of large variety of pesticide brands of changing and sometimes unknown composition which is very difficult to survey. Very old-dateded and cheap formulations are still on the market. This is because the registration system and quality control of pesticides is weak. The oversupply in the industry had led to the situation in which pesticides are now sometimes offered even below production costs. The Chinese government is willing to reduce the toxicity of the pesticides applied in the country and is aiming to make the state-owned pesticides companies profitable. In the long run, therefore, the market environment is likely to improve.

5. Crop Farming and the Use of Pesticides

Economic theory lays down that pesticide use depends on the value of the prevented pest damage in relation to pesticide price. The farmer can influence the output value by the choice of crops which he cultivates, and by the corresponding production technology which he makes use of, including yield-increasing inputs and alternative pest management measures. It is expected that more pesticides will be used on crops which offer a higher return per area and which are treated with above-avearge yield increasing inputs.

A cross-sectional analysis, based on the household data of the First Agricultural Census of China (1997), confirmed the theory postulated in academic literature: more pesticides are applied on those crops with which the highest return can be achieved such as rice, vegetables, cotton, sugar cane, sugar beet, soybean, and tobacco. Further, the use of fertilizer, plastic film and machinery affect pesticide use positively. Labor input has almost no effect on pesticide use since there is underemployment in rural areas and capital inputs are a direct substitute.

These results support the following expectation as regards future pesticide use: ignoring the fact that pesticide supply and pest management measures might change, the development of the use of pesticides will be in line with the general growth trend of the Chinese economy. Further economic growth and the opening of the markets will offer farmers opportunities to find new markets for their high value cash crops, while on the other hand, the government is forced to enhance support for food grain production in order to keep the country self sufficient. Parallel with this, farmers will try to improve labor productivity by investing in yield-increasing inputs. All these trends will increase the tendency on the part of farmers to accelerate their use of pesticides.

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Annex 1: Tobit Model with Upper and Lower Censoring

The model was first introduced by James Tobin and has been expanded in several ways since that time. The base sources applied in this analysis are: Long (1998), Gould et al (1989), Greene (1990), McDonald and Moffit (1980), Maddala (1983); for understanding of econometric and statistical background: Gujarati (1995), Judge et al. (1988)

The Tobit Model

The core of the Tobit model is a simple regression equation:

$$y^* = \beta_o + \beta_1 x_1 + \ldots + \beta_k x_k + \mu_i \quad (k = 1,\ldots,n) \tag{1}$$

Since the dependent variable y is doubly censored such that $0 \le y \le 1$ the linear model is incorporated in a Tobit model which has the two limits 0 and 1:

$$y = \begin{Bmatrix} 0 \; if \; y^* \le 0 \\ y^* = \beta x + \varepsilon_i \; if \; 0 < y^* < 1 \\ 1 \; if \; y^* \ge 1 \end{Bmatrix} \tag{2}$$

The error term of the model ε_i has mean 0 and variance σ^2.

With two limits the likelihood function includes components for upper censoring, lower censoring, and no censoring

Defining:

$$\delta_0 = (0 - x\beta)/\sigma = -x\beta/\sigma \text{ and } \delta_1 = (1 - x\beta)/\sigma \tag{3}$$

$$\Pr(y = 0 | x_i) = \Phi(\delta_0) \tag{4}$$

$$\Pr(y = 1 | x_i) = 1 - \Phi(\delta_1) \tag{5}$$

$$\Pr(0 < y < 1 | x_i) = \Phi(\delta_1) - \Phi(\delta_0) \tag{6}$$

$\Phi(\bullet)$ stands for Cumulative Distribution function (CDF) $\phi(\bullet)$ for the Probability Distribution function (PDF) and

$$CDF = F(x) \Pr[x_i \le x] \tag{7}$$

$$PDF = f(x) = \Pr[x_i = x] \tag{8}$$

$$F(x) = \sum_{i=0}^{x} f(x) \quad (9)$$

Then the Log Likelihood function is (Long 1998):

$$\ln L = \sum_{y=0} \ln \Phi(\delta_0) + \sum_{y=1} \ln\left[1 - \Phi(\delta_1)\right] + \sum_{0<y<1} \ln \frac{1}{\sigma} \phi\left(\frac{y - x_i\beta}{\sigma}\right) \quad (10)$$

This Maximum Likelihood function is estimated using the SAS Software package.

Expected Value, Marginal Effects and Elasticity

The expected value for the uncensored outcome is (Long 1998):

$$E(y^*|x) = E(y|\ 0 > y > 1, x) = x\beta + \sigma \frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} \quad (11)$$

The partial with respect to x_k is :

$$\frac{\partial E(y^*|x)}{\partial x_k} = \frac{\partial E(y|\ 0 > y > 1, x)}{\partial x_k} = \beta_k \left(1 + \frac{\delta_0\phi(\delta_0) - \delta_1\phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} - \left[\frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)}\right]^2\right) \quad (12)$$

The marginal effect of a change in x_k on the probabilities of y being 0, 1 or between 0 and 1 are: (Gould et al 1989):

$$\frac{\partial \Pr(y = 0|x_i)}{\partial x_k} = 1 - [\beta_k / \sigma\ \phi(\delta_0)]\, 1 - [\beta_k \sigma \phi(\delta_0)] \quad (13)$$

$$\frac{\partial \Pr\left(y = 1|x_i\right)}{\partial x_k} = \beta_k / \sigma\ \phi(\delta_1) \quad (14)$$

$$\frac{\partial \Pr(0 < y < 1|x_i)}{\partial x_k} = \beta_k / \sigma\ \phi(\delta_0) - \beta_k / \sigma\ \phi(\delta_1) + \beta_k / \sigma [\phi(\delta_0) - \phi(\delta_1)] \quad (15)$$

The expected value for the observed outcome is (Long 1998):

$$\begin{aligned} E(y|x) &= 0 \times \Pr(y = 0|x_i) + 1 \times \Pr(y = 1|x_i) + E(y^*|x) \times \Pr(0 < y < 1|x_i) \\ &= [1 - \Phi(\delta_1)] + \left[x\beta + \sigma \frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)}\right] [\Phi(\delta_1) - \Phi(\delta_0)] \end{aligned} \quad (16)$$

Differentiating these results the marginal effect of a change in x_k is (Gould et al. 1989):

$$\begin{aligned}
\frac{\partial E(y|x)}{\partial x_k} &= \frac{\partial \Pr(y=1|x_i)}{\partial x_k} \\
&+ \frac{\partial E(y^*|x)}{\partial x_k} \times \Pr(0<y<1|x_i) \\
&+ E(y^*|x) \times \frac{\partial \Pr(0<y<1|x_i)}{\partial x_k} \\
&= \beta_k/\sigma\ \phi(\delta_1) \\
&+ \beta_k\left(1+\frac{\delta_0\phi(\delta_0)-\delta_1\phi(\delta_1)}{\Phi(\delta_1)-\Phi(\delta_0)}-\left[\frac{\phi(\delta_0)-\phi(\delta_1)}{\Phi(\delta_1)-\Phi(\delta_0)}\right]^2\right) \times [\Phi(\delta_0)-\Phi(\delta_1)] \\
&+ \left[x\beta+\sigma\frac{\phi(\delta_0)-\phi(\delta_1)}{\Phi(\delta_1)-\Phi(\delta_0)}\right] \times \beta_k/\sigma[\phi(\delta_0)-\phi(\delta_1)] \\
&= \Pr(Uncensored|x)\beta_k \\
&= [\Phi(\delta_1)-\Phi(\delta_0)]\beta_k
\end{aligned} \qquad (17)$$

The corresponding elasticity can be calculated as:

$$\eta_k = \beta_k\ [\Phi(\delta_1)-\Phi(\delta_0)]\frac{\sum x}{\sum y} \qquad (18)$$

Adoption Ratio

Due to the nature of the two components of the model, probability and functional effect, we can show two aspects of change in pesticide use:

The change in adoption of pesticides application,

$$\frac{\partial \Pr(y>0|x_i)}{\partial x_k} = \beta_k/\sigma\ \phi(\delta_0) \qquad (19)$$

and the change in application of pesticides of those farmers that already apply pesticides

$$\begin{aligned}
&\Pr(0<y<1|x_i)\frac{\partial E(y^*|x)}{\partial x_k} \\
&= [\Phi(\delta_1)-\Phi(\delta_0)]\ \beta_k\left(1+\frac{\delta_0\phi(\delta_0)-\delta_1\phi(\delta_1)}{\Phi(\delta_1)-\Phi(\delta_0)}-\left[\frac{\phi(\delta_0)-\phi(\delta_1)}{\Phi(\delta_1)-\Phi(\delta_0)}\right]^2\right)
\end{aligned} \qquad (20)$$

They add up to the total effect:

$$\beta_k / \sigma \; \phi(\delta_0) + [\Phi(\delta_1) - \Phi(\delta_0)] \; \beta_k \left(1 + \frac{\delta_0 \phi(\delta_0) - \delta_1 \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} - \left[\frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} \right]^2 \right)$$

$$= \frac{\partial E(y|x)}{\partial x_k} \qquad (21)$$

Both components are a product of β_k:

$$\frac{\partial E(y|x)}{\partial x_k} = \beta_k \; [\Phi(\delta_1) - \Phi(\delta_0)] = \beta_k \, \phi(\delta_0) / \sigma \; +$$

$$\beta_k \, [\Phi(\delta_1) - \Phi(\delta_0)] \left(1 + \frac{\delta_0 \phi(\delta_0) - \delta_1 \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} - \left[\frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} \right]^2 \right)$$

$$= \beta_k \left\{ \phi(\delta_0) / \sigma + [\Phi(\delta_1) - \Phi(\delta_0)] \left(1 + \frac{\delta_0 \phi(\delta_0) - \delta_1 \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} - \left[\frac{\phi(\delta_0) - \phi(\delta_1)}{\Phi(\delta_1) - \Phi(\delta_0)} \right]^2 \right) \right\} \qquad (22)$$

From this I introduce the term adoption ratio R_a: the share of elasticity which can be explained by the increase in adoption of pesticides application.

$$R_a = \frac{\phi(\delta_0)}{\sigma [\Phi(\delta_0) - \Phi(\delta_1)]} \qquad (23)$$

Centering

If a set of variables (e.g. crops) is applied which adds up to 1, such as sown area share of crops, interpretability of the estimates can be improved considerably in that the calculated elasticities are centered:

$$\eta_l^c = \eta_l - \sum_{k=1}^{L} \eta_k * \overline{x_l} \quad \text{with} \quad \sum_{k=1}^{L} \overline{x_k} = 1 \qquad (24)$$

Annex 2: Detailed Explanation of Results Tables

The following discussion is a detailed explanation of the content of the tables that were presented for each of the estimates (see chapter 9, Tables 17-24 page 155 et sqq.)

The first column is the weighted mean of each variable. The number corresponds to the measurement units applied in the estimation: crops, fertilizer, film cover, tractor, sowing, harvesting, and pesticide use correspond to sown area share, farm size to hectares of sown area, labor input and other activities of household members to persons per hectare and finally age and school years of the household head to number of years. The "%>0" value in the second column is the share of farms with value of a certain variable larger than zero; this column only applies to the variable with percentage units. "Hypothesis" is the expected result of the hypotheses that have been drawn in chapter 9.

The model results are finally presented in the last three columns: estimated elasticity with corresponding marginal effect and the significance level. Elasticity illustrates the share of change of pesticides use per share of change of the corresponding variable. The marginal effect, on the other hand, illustrates the unit change in pesticide use per unit change of the certain variable. The significance level is the statistical probability that this result is zero.

The means of the crops all relate to the percentage of total sown area e.g. 24 percent of sown area is rice, 24.2 percent is wheat and so on. Since all crops all add up to 100 percent, one crop was omitted for estimation (market with "**"). Thereafter the results were centered by the mean of the elasticities. The significance level of crops indicates whether the result for a certain crop is significantly different from the crop omitted.

Significance levels of non crop variables are always below 10 percent. If the significance level was above 10 percent, the model has been recalculated without the variable (markets with "ns" zero elasticity and marginal effect).

Curriculum Vitae

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