ISBN 0-315-54919-X

Demand Functions for Fertilizer in China

by

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A Thesis
Presented to the University of Manitoba
in Partial Fulfillment of the Requirement for the Degree of
Master of Science
in
Department of Agricultural Economics and Farm Management
Winnipeg, Manitoba

August 1989

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Abstract

As China's arable land is almost fully utilized and wasteland for reclamation is limited, increases in grain output to cope with increased demand from more than 1 billion people have to come from increases in yield per unit of land. Therefore, an accelerated application of chemical fertilizer is the most important measure to make up for the lack of organic fertilizer supply. This study deals with the Chinese farmers' demand for chemical fertilizer based on time series data from 1952 to 1986. Several short-run and long-run models are used to estimate statistically how much of the rate of change in fertilizer demand is contributable to change in each of the exogenous variables, namely, fertilizer/grain price ratio, farm income, technological progress and lagged fertilizer consumption. At the same time, this study analyzes the role of organic fertilizer and prevailing acreage of farmland and predicts future demand for fertilizer based on these econometric models.

The results obtained in this study can be summarized as follows:

(1) Over the period of study, a 10 percent decrease in fertilizer/grain price ratio is predicted to increase fertilizer consumption by 7.7 percent. Similarly, a 10 percent increase in farm income in previous year will result in an increase of fertilizer consumption by 10.5 percent. In addition, the mean elasticity (coefficient) for the time variable is 0.96, indicating that the demand quantity for chemical fertilizer has shifted upward with time and that advancement in science and technology promotes increased total fertilizer demand.

(2) The coefficient for organic fertilizer is not statistically significant, indicating that the effect of the use of organic fertilizer in respect to chemical fertilizer consumption is not significant. Similarly, the coefficient for prevailing acreage of farmland is not significant at the 5 percent significance level partly because the total sown area in China has largely remained the same throughout the analyzed period.

(3) The adjustment coefficient B is 0.97 in long-run model, suggesting that 97 percent of fertilizer consumption in China is adjusted in a period of time in respect to a change in fertilizer/grain price ratio, farm income and technological progress.

(4) The forecasting results in this study are acceptable compared with previous research results released by the Ministry of Chemical Industry (MCI).

Contents

1 Introduction 2

1.1 Agricultural Regions in China 3

1.2 Characteristics of Agricultural Production in China 11

1.3 Literature Review 16

1.4 Statement of the Problem 19

1.5 Objectives of the Study 23

1.6 Organization of the Study 25

2 Historical Background of China's Utilization of Organic and Chemical Fertilizer 30

2.1 Organic Fertilizers 31

2.1.1 Human and Animal Manure 35

2.1.2 Green Manures 40

2.1.3 Biogas Production 42

2.2 Demand, Production and Import of Chemical Fertilizer 45

2.2.1 Demand for Chemical Fertilizer 45

2.2.2 Production and Application of Fertilizer 51

2.2.3 Chemical Fertilizer Imports 55

3 Theoretical Framework of Demand Functions for Chemical Fertilizer (NPK) in China 61

3.1 Theoretical Framework 62

3.2 A Specification of Important Variables 65

3.3 Methods of Analysis 67

3.4 Hypotheses and Assumptions 69

3.5 Data and Exogenous Variables 71

4 An Evaluation and Interpretation of the Empirical Results for the National Demand Functions for Fertilizer 77

4.1 Evaluation of the Results of Short-run Models 78

4.2 Evaluation of the Results of Long-run Models 82

4.3 Forecast of the Demand for Fertilizer 91

5 Summary and Conclusion 97

5.1 Summary of the Study 97

5.2 Implications and Suggestions 100

Appendix

A Chemical Fertilizer Industry since 1949 104

B Tables 119

Selected References 124

List of Figures

1.1 Agricultural Regions in China 6

1.2 July Temperatures and Annual Rainfall 8

1.3 January Temperature and Frostless Periods 10

List of Tables

1.1 Selected Agro-climatic Charateristics of Eight Agricultural Regions of China 27

1.2 Population-land Balance, 1952-1986 28

1.3 Labor Productivity Comparison, 1952-1986 29

2.1 Nutrient Content and Absorption Rate of Organic Fertilizers . 33

2.2 Hog Population, 1952–1986 38

2.3 The Effect of Chemical Fertilizer Use, 1958-1962 46

2.4 The Effect of Chemical Fertilizer Use, 1981-1983 48

2.5 The Effect of Potash Fertilizer Use, 1981-1983 50

2.6 The Production and Application of Fertilizer, 1952-86 58

2.7 The Growth Rate of Chemical Fertilizer, 1953-1985 59

2.8 Chemical Fertilizer Imports, 1952-1986 60

3.1 Fertilizer/grain Price Ratio,1952-1986 73

3.2 Farm Income in China, 1952-86 75

4.1 Statistical Results and Testing in Demand Functions for Chemical Fertilizer in China, 1952-86 89
4.2 Future Demand for Fertilizer, 1989-2000 94
A.1 Investment in Chemical Fertilizer Industry, 1953-1985 107
B.1 Estimated Supply of Organic Fertilizers in China, 1952-78 . . 120
B.2 Estimated Supply of Organic Fertilizers in China, 1979-86 . . 121
B.3 Grain Output in China, 1949-86 122
B.4 Sown Area and Cultivated Area in China, 1952-86 123

Acknowledgement

I wish to express my sincere thanks and appreciation to Dr. Martin H. Yeh, the academic advisor, for his guidance, encouragement and support throughout the preparation of this thesis.

I would also like to thank my committee members, Dr. N.J. Beaton and Dr. R.F. Harris, for reading and criticizing this thesis.

I should thank Mr. Jianjiong Zhu and Mr. Funing Zhong for their support and friendship.

Special thanks to my wife, Yuzhong, for her continual encouragement and financial support during the course of my entire graduate program.

Chapter 1

Introduction

Although China is currently the third largest producer of chemical fertilizer in the world, following the United States and the Soviet Union, it still can not produce enough fertilizer for its own demand. For over three thousand years, Chinese farmers have used organic fertilizers to complement soil fertility. Up to date, organic fertilizers still make up the bulk of total nutrient supply in China even though their supply is limited by the natural resources. Kueh points out that the combined application of both organic and chemical fertilizer has shown a rather coherent trend of constant returns to scale over time [1]. In order to increase agricultural production to satisfy the increased demand for food, employment, raw materials and exports from 1 billion people, chemical fertilizer has to be applied in an accelerated rate. This analysis studies demand for chemical fertilizer in China over the period of 1952–86.

[1]Y.Y. Kueh, "Fertilizer supplies and foodgrain production in China, 1952-1982," Food Policy, Vol. 9, no. 3 (Aug.1984), p. 219.

1.1 Agricultural Regions in China

China's land area covers approximately 9.6 million square kilometers, which is nearly one-fifteenth of the world's total land and which makes China—next to the Soviet Union and Canada— the third largest country in the world [2].

About half of China's land is occupied by Tibet, Xinjiang, Qinghai and Inner Mongolian, which are largely nonagricultural provinces. Its main agricultural area, about 100 million hectares of cultivated land, lies in the eastern half of the country. According to the Soil Institute of the Chinese Academy of Agricultural Science (SICAAS), China's agricultural area can be divided into eight regions (as shown in Figure 1.1 on p. 6) according to the different types of soil, the different application levels of chemical fertilizers, the different nutrient contents in the soil and planting patterns [3].

The Northeast Region (also called the Northeast Plain), covering the territory of three provinces, namely, Heilongjiang, Jilin and Liaoning, is the largest plain in China in a temperate, humid and semi-humid zone. It has 16.41 million hectares of fertile land. The major crops are soybean, corn, spring wheat, sugar-beet and rice. The production of soybean in this region contributes approximately 41.5 percent of the nation's total and 90 percent of the nation's export. At the same time, its corn has been a dominant crop

[2]The China Handbook Editorial Committee, Geography (Beijing: Foregin Languages Press, 1983), p. 1.

[3]SICAAS, Regional Differentiation of Chemical Fertilizer (Beijing: Agricultural Science and Technology Press, 1986), p. 36.

because of high per unit output (4,665 kgs/hectare). It is estimated that about 31.5 percent corn[4] comes from this region in China. Annual precipitation ranges from 300 millimeters to 1,000 millimeters (see Figure 1.2 on p. 8) and the frost-free growing season is 100–180 days (see Figure 1.3 on p. 10). Organic matter content ranges from 1.5 to 4.5 percent. Furthermore, readily available potash is rich in the soil, ranging from 100 to 200 ppm (parts per million) in this region [5]. The application of chemical fertilizer was 1.46 million tons in this region in 1983, including 0.95 million tons of nitrogen (N), 0.47 million tons of phosphate (P) and 48,000 tons of potash (K). The NPK application ratio was 100 : 49 : 5 (SICAAS, 1986). In 1980, the State council decided that a great effort should be made to develop mechanization in the Northeast Plain and accelerate the building of a commodity grain base specializing mainly in the growing of grain and soybean [6]. Many large mechanized state farms are located in this plain.

The Huang-Huai-Hai Region is located south of the Great Wall and north of the Huai River, including all of Beijing, Tianjin, Shandong and Henan, most of Hebei, northern parts of Anhui and Jiangsu. It has a population of 253.36 million and an arable land of approximately 24.56 million hectares. In this region, climate is adequate for crops: annual precipitation ranges from 500 to 1,000 millimeters and the frost-free growing season ranges from

[4]SICAAS, op.cit., p. 36.

[5]Ibid., if readily available potash is less than 70 ppm in the soil, this area should be considered as deficient in potash.

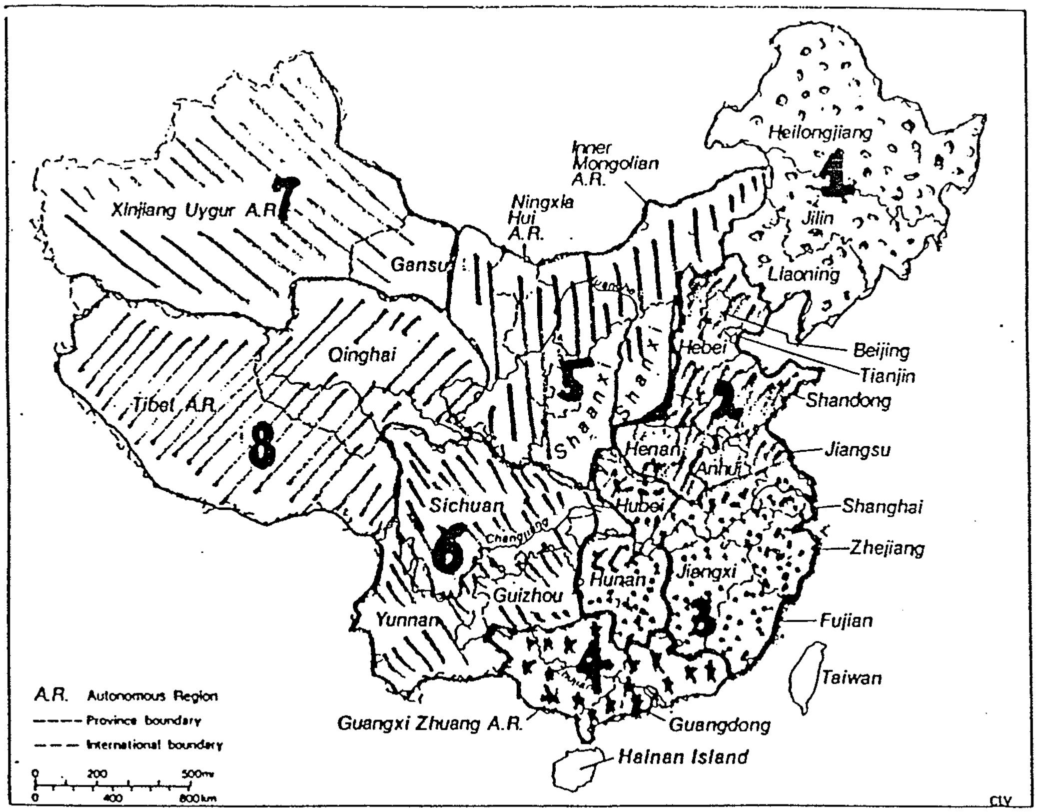
[6]The China Handbook Editorial Committee, op.cit., p. 58

150 to 240 days. Moreover, the multi-cropping ratio is 156 percent and the main crops are wheat, cotton, peanuts and corn. This region produces approximately 66.5 and 66.2 percent of the nation's total wheat and cotton. The soil in some areas of Shangdong has high alkali content, which causes low crop yield. At the same time, organic matter content is 0.6–1.2 percent. The application of fertilizer was 5.37 million tons and the NPK application ratio was 100 : 37 : 4 in 1983 (SICAAS, 1986).

The Middle-Lower Yangtze River Rice Region is well known as the "land of fishes and rice" in China. This region consists of a series of plains of varying width on both sides of the Yangtze River, in the section from the Three Gorges in the west to the coast in the east. It includes all of Hubei, Shanghai, Zhejiang, Jiangxi and Hunan, most of Jiangsu, Fujian and Anhui and has a population of 272.5 million and an area of 7 million hectares of land. Rainfall is high, ranging from 800 millimeters to 2,000 millimeters annually. The frost-free growing season ranges from 210 days to 300 days. The main crops are rice, cotton and rapeseed. In China, about 54 percent of the total rice and 49.5 percent of the total rapeseed are produced in this plain[7]. Furthermore, the Middle-lower Yangtze River Plain is connected with streams, rivers and lakes, including the major fresh water lakes such as Dongting, Poyang, Taihu, Gaobao, Chaohu and Honghu. These rivers and lakes are not only a rich source of fish, shrimps, water chestnuts, lotus seed

[7]SICAAS, op.cit., p. 44.

Figure 1.1: Agricultural Regions in China



1 The Northeastern Region 2 The Huang-Huai-Hai Region 3 The Middle-lower Yangtze River Rice Region 4 The Double-Crop Rice Region 5 The Northern Region 6 The Southwestern Region 7 The Northwestern Region 8 The Qinghai-Tibet Plateau Region

Source: Robert C. Hsu, Food for One Billion: China's Agriculture Since 1949 (Colorado: Westview Press Inc., 1982), p. 2.

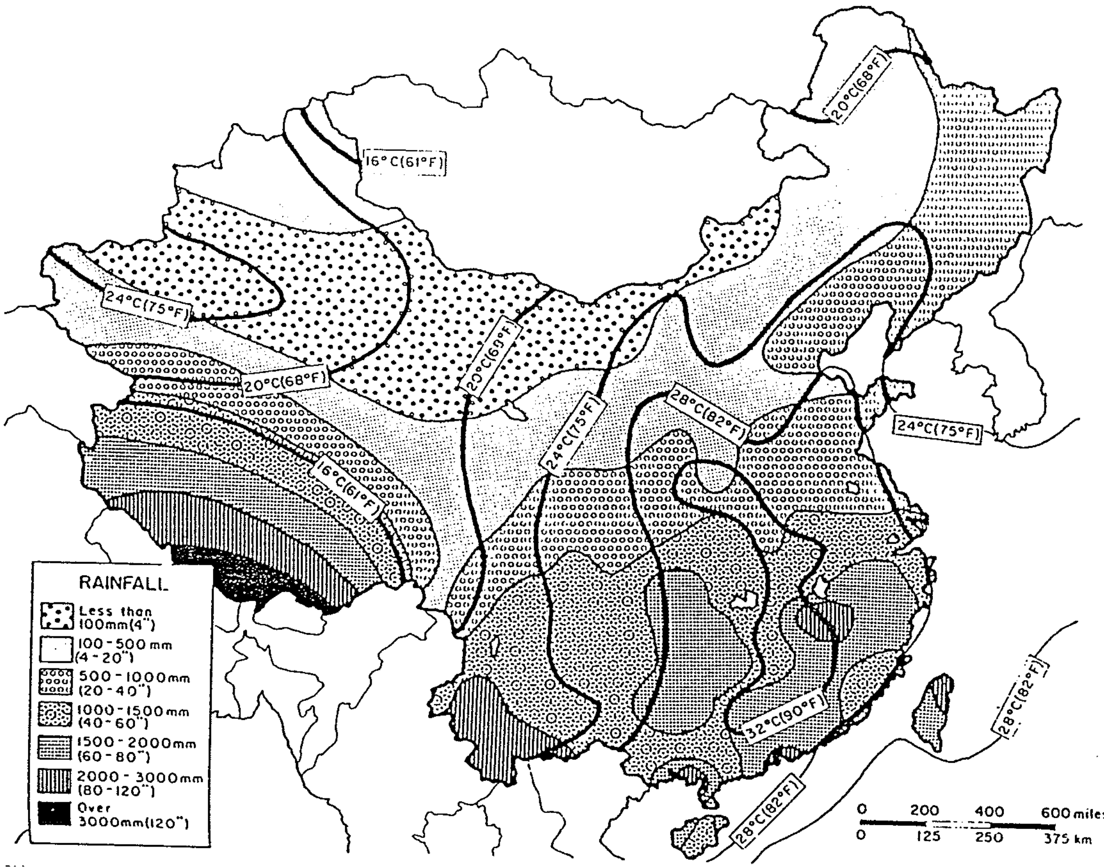
and roots, etc., but also make the region one of the most important grain bases in China. Here, the multi-cropping ratio is 211 percent and organic matter content is 1–3.5 percent in the soil. The application of fertilizer was 4.63 million tons and the NPK application ratio was 100 : 29 : 7.6 in 1983 (SICAAS, 1986).

The Double-Crop Rice Region (southern parts of China) includes all of Guangdon, Guangxi and part of Fujiang. It has a population of 112.4 million and an area of 6.28 million hectares. In this region, annual rainfall ranges from 1,000 millimeters to 2,000 millimeters and crops can be grown during all seasons. The main crops are rice, sweet potatoes and sugar cane. The output of rice is about 90 percent of the total grain [8] production. Here, organic matter content is 1.5–4.0 percent; about 36 percent of soil seriously lacks phosphate while 73 percent of farmland lacks potash. The application of fertilizer was 1.83 million tons while the NPK application ratio was 100 : 29 : 16 in 1983 (SICAAS, 1886).

The Northern Region includes all of Shanxi, Shaanxi and Ningxia, most of Gansu and Inner Mongolia. About 108.67 million people live in this region and 18.5 million hectares of land are available for farming. Rainfall ranges from 200 to 800 millimeters annually and the frost-free growing season ranges from 100 to 210 days.The main crops are winter wheat, corn, millet and potatoes. Because of dry climate and heavy soil erosion, organic matter content

[8] According to Chinese definition, "grain" includes rice, wheat, soybeans, sorghum, millet, other coarse grains and, at one fifth weight, sweet and white potatoes.

Figure 1.2: July Temperatures and Annual Rainfall



Source: Rhoads Murphey, "National Resources and Factor Endowments," in Randolph Barker, ed., The Chinese Agricultural Economy (Colorado: Westview Press Inc., 1982), p. 52.

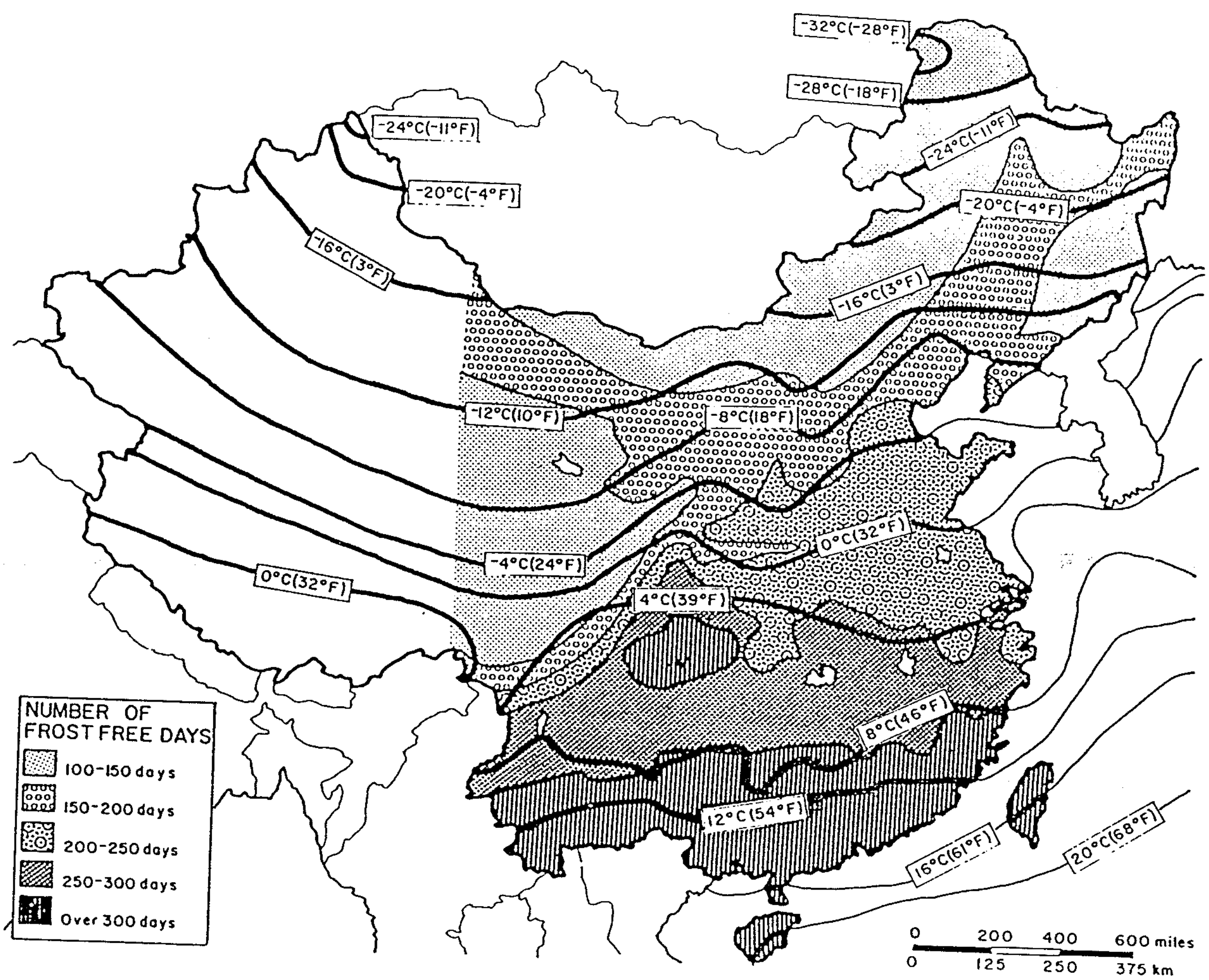
is low, ranging from 1 to 1.4 percent. Of its 18.5 million hectares of cultivated land, 80 percent are not irrigated. As a result, the effect of fertilizer is constrained by weather conditions. In addition, it has an estimated 26.7 million hectares of the grassland in Inner Mongolia. Vast pasture land abundant in water and grasses provides a great opportunity for animal husbandry (SICAAS, 1986).

The Southwestern Region includes Sichuan, Guizhou and Yunnan. This region consists of mostly undulating ground and the hilly areas [9]. It has a population of 162.9 million and an area of 11.27 million hectares. Annual precipitation is around 1,000 millimeters and multi-cropping ratio is 166 percent. The main crops are rice, tea, corn, wheat, potatoes and soybean. Organic matter content ranges from 1 to 2 percent. The southwestern Guizhou and the southern Yunnan seriously lack phosphate and part of the mountain area in Sichuan lacks potash. The application of fertilizer was 1.95 million tons and the NPK application ratio was 100 : 32 : 2.3 in 1983 (SICAAS, 1986).

The Northwestern Region includes all of Xinjiang, part of Gansu and Inner Mongolia. About 16.84 million people live in this area and take care of 3.8 million hectares of land. Because of low annual precipitation, which is less than 250 millimeters, crop production has to depend heavily on irrigation systems. The frost-free growing season ranges from 100 to 200 days and

[9]Department of Propaganda of the Ministry of Agriculture, Animal Husbandry and Fishery, China's Agriculture, Animal Husbandry and fishery are Progressing (Beijing: Agricultural Publishing House, 1983), p. 12.

Figure 1.3: January Temperature and Frostless Periods



Source: Ibid., p. 55.

multi-cropping ratio is 91 percent. The main crops are wheat, corn, cotton and rapeseed. Organic matter content in the soil is 0.2–2.0 percent and about 70 percent soil lacks nitrogen and phosphate. The application of fertilizer was 280,000 tons and the NPK ratio was 100 : 57 : 6.5 in 1983 (SICAAS, 1986).

The Qinghai-Tibet Plateau Region includes all of Qinghai and Tibet, part of Gansu. It has 513,000 hectares of land and a population of 3.65 milllion. The main crops are wheat, potatoes and rapeseed. Per unit of grain output is as low as 1987.5 kgs/hectare. The multi-cropping ratio is only 85 percent, the lowest in China. The application of fertilizer was 21,000 tons and the NPK application ratio was 100 : 51 : 19 in 1983 (SICAAS,1986).

Table 1.1 summarizes agri-climatic characteristics of eight agricultural regions of China. As it can be seen, most regions have a distinct continental climate, a climate of large annual ranges of temperature, frost free period and precipitation.

1.2 Characteristics of Agricultural Production in China

The ultimate economic goal of China before the end of the twentieth century is the modernization of the economy in the shortest possible time. The agricultural sector plays a key role because it has to feed more than 1 billion people, on 7 percent of the world's arable land. From 1952 to 1986, grain output grew at an annual rate of only 2.59 percent while population growth averaged 1.81 percent [10]. As a result, agricultural growth did little more than keep pace with the expansion of the population. As well, population growth reduced the margin of surplus for investment and farmers had to use more labor than expensive nonlabor inputs. By the end of 1977, although China had reclaimed 17 million hectares of land, which contributed significantly to agricultural development and food production for the mass population, the increase was offset by 27 million hectares of arable land used for building roads, houses, factories, schools and agricultural enterprises [11]. Thus arable land per capita was reduced by more than half between 1952 and 1986 (Table 1.2). At the end of 1970s, arable land per farmer in China was roughly 0.33 hectare, which was smaller than that in other developing countries, such as Bangladesh (0.43), Indonesia (0.63), Philippines (0.91) and India (1.0) [12].

After feeding the population, agriculture had to carry out its second important task: providing employment opportunities for those millions of rural people. By no means, unfortunately, can urban industry provide additional jobs for those other than urban residents. The government has to keep rural population from flowing into the cities for jobs because these cities are already over-crowded and short of housing and public services. Between 1952

[10]Calculated from data in China's Statistical Yearbook 1987, p. 5 and p. 170. China's Statistical Yearbook is released by Chinese State Statistics Bureau (SSB) every year.

[11]Chia-liang Wang, "Given Serious Attention to the Study of Land Problems," People's Daily, April 9, 1982.

[12]Nicholas R. Lardy, Agriculture in China's Modern Economic Development (Combridge University Press 1983.), p. 5.

and 1986, when the Chinese labor force increased from 207.3 million to 512.8 million, agriculture employed about 65 percent of 305.5 million new workers [13]. Consequently, the share of employment in this sector shrank from about 84 to 61 percent of the total over the same period [14].

Although the average growth rate of the labor force in industry increased faster compared with the same rate in agriculture, its share of the labor force in 1986 was only 17.5 percent [15]. Industry in 1986 contributed 59 percent to the overall gross value of national production while agriculture, employing more than 60 percent of the labor force, produced only 21.2 percent [16]. If agriculture is compared with industry, labour productivity is much lower in agriculture. In 1986, each worker contributed 13,310.6 yuan to gross value of national production while each farmer contributed only 736.6 yuan at 1952 price (as shown in Table 1.3). From 1952 to 1986, labor productivity in agriculture grew at an annual rate of 3.03 percent while labour productivity in industry grew at 4.7 percent [17]. Thus, the advantage of full employment in agriculture is mainly to provide a living for rural people and keep them from overcrowding the cities.

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[13] Calculated from data in China's Statitical Yearbook 1987, p. 25.

[14] Ibid., p. 135.

[15] Ibid., p. 224.

[16] Gross value of national production was 1896.1 billion yuan in 1986 price. Gross value of industrial production and gross value of agricultural production were 1119.4 and 401.3 billion yuan in 1986 price, respectively. For more detail, see SSB, China's Statistical Yearbook 1987, p. 35. Yuan is Chinese currency. 1 U.S. dollar was equal to 3.81 yuan in 1986.

[17] Calculated from data in China's Statistical Yearbook 1987, p. 26.

Although the role of agriculture may be emphasized by the government as the foundation of the economy, investment in this sector has been allocated inadequately either directly to agriculture or to industry which produces inputs for agricultural production. Up to 1980, the share of national investment budget that China spent on agriculture for irrigation systems, rural transportation and chemical fertilizers averaged 11.9 percent. From 1981 to 1985, not only capital construction in agriculture declined, but the share of national investment in agriculture was reduced to the average rate of less than 6 percent and it was even scaled down to only 3.3 percent in 1986 [18]. According to Nicholas R. Lardy, an American specialist on Chinese agriculture at the University of Washington, the share of national investment spent on agriculture is now the lowest since the government was established in 1949 [19]. This downward trend may connect with the recent emphasis on investment in energy production, chemical industry and transportation, which only partially benefits agriculture [20].

Moreover, government policy has strongly influenced the agricultural sector. Evidence to date indicates that the Chinese leaders have oscillated between two approaches to developing agriculture. One approach emphasizes the socialist ideology, collective organization and moral incentives. The

[18]These numbers came from He Kong's report. He Kong is Minister of Agriculture. For more detail, see People's Daily, June 3, 1988.

[19]Los Angeles Times, late December, 1988.

[20]OECD(the Organisation for Economic Co-operation and Development), Agriculture in China (Paris, 1985), p. 13.

other prefers more material incentives, family farming and economic freedom [21]. Past experience suggests that farmers are more interested in material gains and freedom than in socialist ideology and moral incentives. For example, a "land reform" program was carried out from 1950 to 1952 after the Communist took over in 1949. The aim of this land redistribution was to destroy thoroughly the social foundation of the Nationalist government. The program forced landlords and rich peasants to give up their land with no compensation payments. Peasants who obtained land which they had wanted for generations understood that they should support the Communist Party if they didn't want their land to be taken back. As a result, incentives were created and agriculture recovered quickly from the Second World War and the Civil War. In 1958, grain production reached a new peak of 195.3 million tons without any increase in the use of modern inputs. This means a total 20.5 percent increase in only six years [22].

During the period of the Great Leap Forward (1958-60), the government abandoned the use of prices and markets as an instrument of resource allocation in agriculture and forced farmers to give up the ownership of their land for joining the People's Communes which were made the basic units of socialist organization in the rural areas. Consequently, farmers couldn't determine their patterns of cropping at that time. Their private plots were

[21] Hsu, op.cit., p. 3.

[22] Colin A. Carter and Fu-Ning Zhong, China's Grain Production and Trade (Colorado: Westview Press Inc., 1988), p. 4. Their figures on grain production prior to 1964 have been adjusted by applying grain conversion rate of one fifth weight to potatoes.

eliminated and their surplus products after quotas were no longer allowed to sell in the free markets. Therefore, the new policy created disincentives in agriculture. Because of the failure of this policy and poor weather conditions, grain production dropped from 200 million tons in 1958 to 147.5 million tons in 1961 and agricultural production declined by 4.3 percent from 1958 to 1962 [23]. Such a combination created economic difficulties and starvation began to spread nationwide. The death rate dramatically increased from 1.08 percent in 1957 to 2.54 percent in 1960 [24], which has remained the highest to date. As Lardy points out, although the motives of those political campaigns may be complex, their economic effects are straight-forward: declining efficiency of resource use and, for given investment allocations, slower growth, and sometimes even negative growth of agricultural production.

It can be seen from the discussion above that many constraint factors affect the development of agriculture. In the near future, how to avoid man-made problems and keep agricultural policy stable is one of the top priorities.

1.3 Literature Review

Although many researchers have studied Chinese agricultural production for years, only a few concentrate on the area of either chemical fertilizers or organic fertilizers. Up to the present time, little work has been done in China in estimating aggregate demand functions for fertilizer. A majority of stud-

[23]Calculated from the data in China's Statistical Yearbook 1987, p. 132.
[24]Ibid., p. 83.

ies associated with chemical fertilizers, organic fertilizers or trace elements focuses on a certain crop with respect to the impact of these fertilizers on a certain area. Many Chinese scholars used to estimate demand for chemical fertilizers by simply calculating the balance of soil nutrient content according to soil test results and predicted growth rate of grain. Even though those studies provide very useful information, more involvement of quantitative analyses is needed while demand functions for fertilizer are estimated.

Bruce Stone analyzes issues of growth, balance, allocation, efficiency and response in Chinese fertilizer application in the 1980s and 1990s. He believes that the increasing volume, quality and efficiency of modern input and labor use have made Chinese agriculture the most successful among developing countries during the last three and a half decades [25]. According to his analysis, fertilizer production in China could surpass the United States by 1990 but supply would not satisfy the demand because of high population pressure and arable land constraint [26]. As a result, China will continue to import fertilizers until the year 2000.

It seems that allocation system is too closely tied with procurement. Particular grain crops of greater interest to the state authorities have received higher per unit fertilizer allocation in high yield areas. Stone points out there are no allocations to certain poor land grain crops such as roots and tubers,

[25] Bruce Stone, Chinese Fertilizer Application in the 1980s and 1990s: Issues of Growth, Balance, Allocation, Efficiency and Response (Washington,D.C.: International Food Policy Research Institute 1985).

[26] Ibid., p. 454.

beans and coarse grains [27]. Consequently, China is beginning to face a more serious situation of diminishing returns in the major growing regions. He also stresses his concerns with the fact that most of the effort to develop the chemical fertilizer industry has been focused on nitrogen. The marginal response ratio of nitrogen may drop because other nutrients become constraints. However, he suggests that more attention must be paid on the production and application of phosphate, potash and trace element fertilizers.

For centuries, Chinese farmers have struggled to maintain soil fertility by using organic fertilizers. However, increased demand for grain from an ever-increasing population, reduced per capita arable land resource and heavy erosion of soils call for large quantities of chemical fertilizer to increase grain output and build depleted soils. Therefore, it is very important for China to build its own chemical fertilizer industry. Leslie T.C.Kuo studied the development process of the Chinese chemical fertilizer industry from pre-Communist days to the 1970s [28]. Detailed information and analyses can be considered as his outstanding contributions. He also predicted that China would have to import a considerable amount of chemical fertilizer for many years even though the production, distributionn and application of chemical fertilizers have been improved.

Y.Y. Kueh argued that the whole of China's agriculture tended to move

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[27]Ibid., p. 462.

[28]Leslie T.C. Kuo, Agriculture in the People's Republic of China (New York: Praeger Publishers, Inc., 1976).

along a general path approximate to constant returns from the application of both chemical and organic fertilizers during most of the last three and a half decades [29]. The major portion of his study was organic fertilizers. The annual quantity of different organic manure forms was estimated. At any rate, his estimate differs consistently from that of other previous efforts and can be considered the best recent effort.

1.4 Statement of the Problem

China has 960 million hectares of land. Only a little more than 100 million hectares are cultivated [30], which include part of the low-yield land such as saline and alkaline land, low-lying land, sandy land and other types of poor and extremely unproductive land. Cultivated land has been reduced at the annual rate of more than 5 million mu [31] by constructing houses, factories, schools and agricultural enterprises [32]. Although the absolute amount of land in China is large, the average amount of cultivated land per capita is less than 0.1 hectare, which is only 27 percent of the world average. Since the average grassland per capita in China is 0.3 hectares, less than one-half of the world average [33], the limitation of cultivated land per capita can not

[29]Kueh, op.cit.

[30]SICAAS, op.cit., p. 10.

[31]1 hectare is equal to 15 mu.

[32]"To Use Farmland Efficiently and Protect it are China's Long-run Policies," People's Daily, March 7, 1985.

[33]Sylvan Wittwer, ed., Feeding A Billion, Frontiers of Chinese Agriculture (Michigan State University Press, 1987), p. 36.

be made up by the grassland.

It is estimated that 13.3 million hectares of wasteland can still be reclaimed for farming and another 13.0 million hectares of marshes and tideland remain for forestry, animal husbandry and fisheries [34]. Most wasteland is located in the remote areas of Heilongjiang Province and the Xinjiang Autonomous Region. At one time there were ambitious plans for opening up wasteland in Xinjiang, but it has become clear that water resources may not be enough to irrigate the present cultivated area. Compared with the rising yield per unit of land, reclamation is a longer, slower and more costly process of increasing agricultural production. However, large land reclamation projects have been carried out by the central government. New reclamation projects will not only mobilize many people to those areas, but also will be required a huge amount of capital to build irrigation systems, transportation systems, houses, public health facilities, local industry, and electric power, etc. Moreover, land impovement is necessary because the yield of newly reclaimed land is low.

Although China is the third largest consumer of manufactured fertilizer in the world [35], it still needs great amounts of fertilizer to reduce the farmland's deficiency in nitrogen, phosphate and potash. According to a survey of 156 field experiments in 14 provinces beginning in 1935, 75.7 per cent of Chinese farmland was deficient in nitrogen, 37.7 percent in phosphate and 7.7 percent

[34] These figures come from He Kong's report. For more detail, see People's Daily, June 3, 1988, p. 1.

[35] Food and Agricultural Organization of the United Nations, FAO Fertilizer Yearbook 1983, Volume 33, p. 120-121.

in potash [36]. Another report, published in 1962, estimated that 80 per cent of farmland was deficient in nitrogen [37]. A new survey of China's soils in 1987, released by the Chinese Academy of Agricultural Science, estimated that approximately 66 percent of China's good farmland contains only 3–6 percent organic material, which is just about the average world level.

As most of the land suitable for cultivation has been utilized for crop production, further extending areas for food production over the period from 1950s to 1970s has resulted in the destruction of forests and grassland, and the draining of lakes. Such abuse of land resources has thus caused serious losses from water and wind erosion. Since the mid 1960s, encroachment of desert land has increased by 3 million hectares [38]. To improve the quality of the highly erodible soil, estimated about 1.2 million square kilometers, the more use of organic fertilizer is necessary.

The new agricultural policy, which is called "responsibility system," was passed by the Third CCCP Plenary Session in 1978 [39]. The collective farmland is now reallocated to the individul households which are required to submit a fixed proportion of the output to the state by contracts. Currently, farmers have their rights to manage their farms. For short-term benefits, they tend to use more and more chemical fertilizer to raise yields, thus ne-

[36]Op.cit., SICAAS. According to Bruce Stone, this survey included 170 field experiments and 74 percent of Chinese farmland was deficient in nitrogen.

[37]According to Li Qinggui in Renmin Ribao (People's Daily) December 25, 1962, 80 percent of Chinese farmland was deficient in nitrogen.

[38]Op.cit., Wittwer, p. 36.

[39]The full name of CCCP is Central Committee of the Communist Party.

glecting the use of organic fertilizer to compensate the fertility of the soil. According to a new report [40], the average organic material content in China's cultivated land has been reduced to only 1.5 percent, which is far below the world average of 3.0 percent. The recent downward trend in the use of organic fertilizer may result in a further decline of land fertility and may cause negative effects in the long run.

As the size of the population and the standard of living of the society changes, there is no doubt that the demand for food will continuously increase in China. Further development in agricultural production can not depend on those reclaimation projects discussed earlier because there are too many constraint factors. Therefore, the emphasis has to be put on increases in yields per unit of land by using more modern inputs such as farm machinery, new varieties, irrigation and chemical fertilizer on low and middle yield areas and increases in land fertility by the more efficient use of both chemical and organic fertilizers.

The development of agricultural mechanization has been constrained by the existence of surplus labor in China. Although farm machinery can replace labor wherever it is in short supply such as in newly developed regions or during peak periods of harvesting, most of the work in the field is still done by labor and draft animals. Therefore, the emphasis in agricultural mechanization should be shifted to improve the quality of tractors and other

[40] "Declining Fertility of Farmland has caused Serious Problems in Agricultural Production," People's Daily, July 23, 1988.

kinds of farm machinery.

For centuries, water-control projects in China have been constructed and improved for the purposes of flood control and irrigation. At present, about one-half of China's cultivated land, most located in south, is irrigated. The north does not have enough drainage facilities to control severe floods and adequate irrigation systems to reduce the damage of droughts because water resources are deficient and unevenly distributed in this area. Therefore, China has been considering large-scale diversion of water from the Yangtze River to areas north of the Huanghe [41]. The project will be costly and may cause a water shortage along the middle reaches of the Yangtze River. Thus it is unlikely that this project will be constructed in the near future.

Because organic fertilizers are necessarily limited in supply, further efforts of increasing yields per unit of land have to be put into more application of chemical fertilizer. Therefore, demand for fertilizer in China is analyzed in detail in this study.

1.5 Objectives of the Study

Little work on the demand for chemical fertilizer has been done in China. This study, based on time series data from 1952 to 1986, focuses on demand functions for total fertilizer use in China. Several regression models are employed to estimate demand for fertilizer. In this study, demand for fertilizer

[41] Hsu, op.cit., p. 63.

is a function of fertilizer/grain price ratio, prevailing acreage of farmland, farmers' annual income and time trend variable which stands for technological progress. This study utilizes up-to-date official statistical information released by State Statistical Bureau (SSB). In the past, researchers had to estimate data on their own. Their estimates were prepared under most difficult conditions and were different from one another as a result of the scarcity of official statistical data. Hence, this study may provide more complete and accurate results than the previous efforts in estimating demand for fertilizer.

Theoretically, the demand for fertilizer essentially depends on the price of fertilizer, the price of agricultural products, technological progress, and other economic variables [42]. Moreover, the fertilizer price is set by the fertilizer firms based on production cost, production capacity, improved technology and market conditions under the context of perfect competition [43]. As a result, a recursive model is more appropriate first to derive the price of fertilizer, and then to estimate the demand for fertilizer [44]. In China, unfortunately, the price of fertilizer has been set by the government and does not fluctuate as it should be. Therefore, a fertilizer/grain price ratio is used as a substitute for fertilizer price. As a result, this ratio is treated as an exogenous variable

[42] E.O. Heady and L.G. Tweeten, Resource Demand and Structure in the Agricultural Industry (Iowa: Iowa State University Press, 1963).

[43] According to microeconomic theory, no firm can set the price under the prefect competition condition.

[44] M.H. Yeh, D.F. Kraft and S.Y. Sun, A submodel of Fertilizer Demand and Prices in Eastern and Western Canada. A working document prepared under DSS contract funding for the Agriculture Canada, Agricultural Sector Modelling Project, 1979.

and a single equation is used in this study.

This study has the following objectives:

(1) recognizing the constraint of supply of organic fertilizers by the natural resources and the importance of organic fertilizers in agricultural production;

(2) reviewing the historical development in fertilizer production and application since 1949;

(3) using regression analysis to estimate total demand for chemical fertilizers in deriving price and income elasticities of fertilizer;

(4) predicting the future demand for chemical fertilizers to 2000.

1.6 Organization of the Study

The study is divided into five chapters.

Chapter 1 , an introduction of the study, states the problem.

Chapter 2 provides historical background of China's utilization of organic and chemical fertilizer. Over thousands of years, Chinese farmers have developed the advanced technology of recycling organic fertilizers. At present, organic fertilizers still make up the bulk of total nutrient supply, especially potash and trace elements, in Chinese agriculture. At the same time, the utilization of chemical fertilizer yields diminishing return in some high-yield regions but the combined application of both types of fertilizer can maintain a constant return. Because organic fertilizer is constrained by the natural source supply, chemical fertilizer plays an important role in agricultural production. This chapter also provides a historical review of chemical fertilizer imports.

Chapter 3 provides a theoretical framework of demand functions for fertilizer. It describes hypotheses and assumptions and analyzes exogenous variables. Furthermore, it specifies demand functions and discusses methods of analysis in detail.

Chapter 4 presents the empirical results from different models and provides interpretation and implications. At the same time this chapter also provides the forecasting results of fertilizer demand to 1990s. It uses several methods to obtain unbiased forecastings, which are compared with previous results conducted by different authors.

Chapter 5 concludes the thesis and points out the direction for future research.

Table 1.1: Selected Agro-climatic Charateristics of Eight Agricultural Regions of China

Region	Cropping index	Frost free period (days)	Average January temperature (C degree)	Average July temperature (C degree)	precipitation (mm/year)	major crops
1	100	100 to 180	-13 to -23	22 to 23	300 to 1000	corn soybean
2	156	150 to 240	-4 to -7	26 to 28	500 to 1000	wheat cotton
3	211	210 to 300	7 to 10	27 to 29	800 to 2000	rice cotton
4	189	340 to 365	14 to 15	27 to 28	1000 to 2000	rice tubers
5	102	100 to 210	-8 to -16	20 to 24	200 to 800	wheat corn
6	166	260 to 340	5 to 9	21 to 25	1000 to 1200	rice tea
7	91	100 to 220	-12 to -16	16 to 24	less 250	wheat corn
8	85	–	0 to -8	10	500 to 1000	wheat potatoes

Source: SICAAS, Regional Differentiation of Chemical Fertilizer (Beijing: Agricultural Science and Technology Press, 1986) and Randolph Barker, "Prospects for Growth in Grain Production," in Randolph Barker, ed., The Chinese Agricultural Economy (Colorado: Westview Press Inc., 1982), p. 171, table 11.2.

Table 1.2: Population-land Balance, 1952-1986

Year	Arable land million of hectares (1)	Population millions (2)	Agricultural labor force millions (3)	Arable land per capita (1) ÷ (2)	Arable land per farmer (1) ÷ (3)
1952	107.92	574.82	173.17	0.190	0.62
1956	111.82	628.28	185.45	0.180	0.60
1965	103.60	725.38	233.98	0.140	0.44
1970	101.13	829.92	278.14	0.120	0.36
1979	99.50	975.42	294.25	0.100	0.34
1982	98.61	1015.41	320.13	0.098	0.31
1986	97.21	1057.21	379.89	0.092	0.26

Source: column 1 is from The Strategy of Rural Development in China (Beijing: Agricultural Science and Technology Publishing House, 1985), p. 795. Column 2 and 3 are from China's Statistical Yearbook 1984, p. 81 and p. 109. The figure of arable land in 1986 is author's estimate based on different sources, others are from China's Statistical Yearbook 1987, p. 89 and p. 135.

Table 1.3: Labor Productivity Comparison, 1952-1986

Year	GVIP billion yuan (1)	GVAP billion yuan (2)	Industry labor force (3)	Agricultural labor force (4)	Contribution per worker (1) ÷ (3)	Contribution per farmer (2) ÷ (4)
			million	million	yuan	yuan
1952	34.9	46.1	12.46	173.17	2800.9	266.2
1956	71.51	55.55	13.75	185.45	5200.7	299.5
1965	158.06	63.20	18.28	233.98	8646.6	270.1
1970	274.70	76.66	28.09	278.14	9779.3	275.6
1979	558.96	105.85	53.40	294.25	10467.4	359.7
1982	739.08	141.39	59.30	320.13	12463.4	441.7
1983	816.69	154.85	60.23	325.10	13559.6	476.3
1986	1195.29	230.64	89.80	313.11	13310.6	736.6

Note: Production values are counted in 1952 prices. GVIP is gross value of industrial production and GVAP is gross value of agricultural production. Source: SSB, China's Statistical Yearbook 1987, p. 115. Agricultural labor force data exclude employment in rural small-scale factories managed by the commune level or above but include workers of state farms.

Chapter 2

Historical Background of China's Utilization of Organic and Chemical Fertilizer

This chapter provides the historical background of China's utilization of both organic and chemical fertilizer. At present, organic fertilizer still plays an important role as a source of nutrient supply. Although the process of substitution of chemical for organic fertilizer has been adopted since the mid-1970s, these two types of fertilizer are not "prefect substitutes". For instance, the low and declining organic content of Chinese soils can not be complemented through the application of chemical fertilizer. Furthermore, potash resources are seriously lacking in China and the application of manufactured potash is far from adequate. Therefore, organic fertilizers provide most of potash that crops need. As a result, the combined application of both types of fertilizer has to be emphasized.

2.1 Organic Fertilizers

Chinese farmers have used organic fertilizers for over three thousand years [1]. According to Chinese agricultural documentaries, Xunzhi and Liji, written over 2,000 years ago, human and animal wastes, plant ashes and grasses were used to increase crop output and improve soil fertility at that time. For centuries, Chinese agriculture has relied heavily on the organic fertilizers to feed an ever-increasing population. One reason that most of the land remains productive after so many years of cultivation is the use of organic fertilizers.

In the 1950s, soon after the founding of the People's Republic of China, farmers were encouraged to collect as much organic fertilizer as they could to raise crop yield and output due to insufficient domestic fertilizer production. Although the application of chemical fertilizers had rapidly increased and reached 19.30 million tons in nutrient weight by 1986 [2], the government policy still remained "walking on two legs," which means that the application of both chemical fertilizers and organic fertilizers should be emphasized.

Organic fertilizers can be divided into four groups depending on the manure resources. First are those manures collected and prepared on the farm, including human and animal wastes, by products of biogas fermentation, crop residues, oil cakes, plant ashes, river and pond mud, etc. Second are green manures, which include wild or cultivated plants that are plowed under

[1]Han Sun, "Organic Farming–Growing Plants," in Sylvan Wittwer, ed., Feeding A Billion, Frontiers of Chinese Agriculture (Michigan State University Press, 1987), p. 111.

[2]See Table 2.6.

while green. Third are the peats and humic manures, which are the decaying residues of plants at the bottom of lakes and the mixed manure with peat and minerals, respectively. The last are industrial wastes containing certain amount of nutrients. Chinese farmers have used almost all materials which can be decomposed in the soil and can release soil nutrients (Han Sun,1988).

Table 2.1 lists the average plant nutrient content and absorption rate of various organic fertilizers used by Chinese farmers. Compared with Kueh's estimate, the value of plant nutrient content in this table is low because it is based on decomposed excreta rather than raw excreta. Considering the enormous size of China's territory, the actual nutrient content may vary considerably from place to place and from time to time. As a result, it is worth assuming that the nutrient content of organic fertilizer is constant over time.

Many scholars have agreed that it is difficult to achieve an exact estimate for absorption rate because it varies with differences in decomposed time periods for organic fertilizers, soil conditions and plant crops, etc. First, the nutrients contained in organic fertilizers have to decompose in a period of time. A portion becomes readily available for plant root systems and some of the other portions can build up in the soil and be released during future time periods. Sometimes this decomposing process takes a long time and the unabsorbed nutrients may be eroded away by water and wind. Therefore, the storage period for organic fertilizers should be controlled to minimize the

Table 2.1: Nutrient Content and Absorption Rate of Organic Fertilizers

Type of fertilizer	*Nutrient content*				*Absorption rate*
	N	P_2O_5	K_2O	Total	
Night soil	0.6	0.2	0.3	1.1	45
Hog manure	0.5	0.4	0.5	1.4	20
Draft animal manure	0.6	0.3	0.8	1.7	20
Plant residues	0.3	0.2	0.6	1.1	30
Oilseed cakes	7.0	1.3	2.1	10.4	65
Green manure	0.4	0.1	0.4	0.9	65
River and pond mud				0.2	10

Source: Kang Chao, Agricultural Production in Communist China, 1949-1965 (Wisconsin: The University of Wisconsin Press, 1970), p. 145, table 6.1.

loss of nitrogen. Second, different types of soil have various humus contents, physical and chemical properties and structures, which cause the percentage of nutrient content to be changed. The higher is the percentage of nutrient content, the higher the absorption rate. Third, plant roots can absorb the nutrients only within their reach and different crops have different root systems. A portion of the nutrients can not be absorbed by certain crops simply because it can not be reached by their roots even though a large amount of fertilizer is applied.

As was discussed earlier, domestic fertilizer production was insufficient in the 1950s. The central government increased its pressure on rural communities to collect more organic fertilizers. Because night soil and animal manure was almost fully utilized by Chinese farmers, especially in the "high and stable yield " rice region where there was denser human and animal population, farmers had to collect fertilizers with low nutrient content, such as river and pond mud, to satisfy the government's demand. According to a report, all rivers, ponds and aqueducts in Gangsu province were "bottom up" by 1957[3]. Although the amount of organic fertilizers collected increased dramatically, total plant nutrient might not increase significantly due to an extremely low nutrient content in the fertilizers.

In 1958, provincial and local governments even set higher targets for farmers to achieve. Consequently, the extent of statistical exaggeration was beyond the limitation of natural resources and human abilities. Chao had a good example to explain the situation. He wrote:

"The Anhuei Daily, provincial newspaper of Anhwei Province, reported in August 1958 the achievements attained in six localities. The average amount of fertilizer applied per mou in 1958 ranged from 93,750 kg to 419,350 kg. Using the highest figure would mean that 628 kilograms of fertilizers were applied to each square meter of land surface. Whatever materials the so-called fertilizers might be, this amount would be more than enough to bury a small tree, let alone a rice plant."

High targets set by governments caused serious problems besides the wildly exaggerated statistics. First, a considerable amount of labor was wasted in collecting organic fertilizers. Many localities reported that 30-40 percent of

[3]Op.cit., Chao, p. 148.

the labor force had been mobilized without compensation payments to collect organic fertilizers[4]. It is estimated that about 180 person days per hectare are required to collect river and pond mud and to dig pits for preparing decomposed manure (The manure is mixed river and pond mud with rice straw, milk vetch and hog manure.)[5]. Because river and pond mud was removed year after year, it was no better than ordinary dirt. Second, the top layer of grassland was removed as fertilizer in several southern provinces, which caused severe erosion problems because many green hills and slopes had become bare [6]. Third, some nutrients were even injurious to crops because they were either too acid or too alkaline to be used.

Government policy changed when the domestic fertilizer production increased. "Walking on two legs" was emphasized and the production of green manure was encouraged because the labor requirement of green manure production was minimized and nutrient content of green manure was high.

2.1.1 Human and Animal Manure

Human and animal wastes are valuable manure sources because of their high nutrient content and availability. According to an estimate, the mean annual excreta per person is 90 kilograms of feces and 350 kilograms of urine. All these wastes contain 39 kilograms of organic matter, 2.65 kilograms of nitro-

[4] Ibid.
[5] Op.cit., Sun, 113.
[6] Op.cit., Chao, p. 149.

gen, 0.93 kilograms of phosphorus and 1.0 kilograms of potassium [7]. Based on these basic figures, about 40 million metric tons of organic matter and 4.6 million metric tons of nitrogen, phosphorus and potassium nutrients are available annually in China.

Since 1949, hog raising has been encouraged because hogs provide not only the principal meat consumed by the Chinese, but bristles, hides and high nutrient content manure. *National Program for Agricultural Development*, 1956-67, required each household in the rural areas to raise an average of 2.5 to 3 hogs by 1967 except in the Moslem areas [8]. As a result, the number of hogs increased in spite of several periods' fluctuations in 1950s. From 1949 to 1954, the hog population grew rapidly because hogs were raised by individul farmers. It declined in response to changes of government policy from 101.7 million in 1954 to 88 million in 1955 and 84 million in 1956 [9]. In this period the government required farmers to join cooperatives. Farmers began to worry as to whether their properties such as draft animals and hogs would change ownership. Although the government did not force farmers to submit their hogs to cooperatives with or without compensation payments, many hogs were slaughtered. In 1957 the government restored the empha-

[7]Op.cit., Sun, p. 114. According to Kueh's estimate, the mean annual excreta per capita contains 6.6 kilograms of nutrient (4.25 kg N, 1.3 kg P_2O_5, 1.05 kg K_2O) while nutrient coefficient is 1.32%. This nutrient coefficient refers to raw, rather than decomposed excreta. Other scholars may use the lower coefficient which is based on decomposed excreta.

[8]Op.cit., Kuo, p. 142.

[9]For more detail, see table 2.2.

sis to private hog raising and as a result, the hog population rose to 146 millions [10], but the increasing trend didn't remain for long. The hog population declined again in 1958–1960 because of communalization [11]. Due to the failure of collectivization policy and low grain output, the shortage of fodder in particular became a major problem. Consequently, the number of hogs dropped dramatically to 82 million in 1960 and 75 million in 1961 (see Table 2.2). From 1962 to 1966, agriculture slowly recovered from huge losses of grain production caused by the failure of agricultural policy and natural disasters. As the supply of fodder increased, the hog population rose steadily. In 1966 the number of hogs reached a peak of 193 million when "the Cultural Revolution" expanded nationwide. Not until 1970 did it stop dropping because of negative effects of this power struggle. From 1970 to the present, the increase in hog population has been comparatively stable except the insignificant reduction in several years. By the end of 1986, the number of hogs had risen to 337 million.

If an average feeding period is 8 months, the mean excreta per hog is 950 kilograms of feces and 1,250 kilograms of urine. However, each hog can provide 173 kilograms of organic matter, 8.5 kilograms of nitrogen, 4.8 kilograms of phosphorus and 9.8 kilograms of potassium. Based on a rough estimate,

[10] Ibid.

[11] In April 1958, twenty-seven collectives in Honan Province merged into a new organization, which was named "People's Commune". When a people's commune was established, the collective ownership was transformed into ownership by the people as a whole. Private plots were eliminated. By the end of 1958, the whole countryside had been completely communized.

Table 2.2: Hog Population, 1952–1986

Year	Hog population (10,000)	Year	Hog population (10,000)	Year	Hog population (10,000)
1952	8977	1964	15247	1976	28725
1953	9613	1965	16693	1977	29178
1954	10172	1966	19336	1978	30129
1955	8792	1967	19006	1989	31971
1956	8043	1968	17863	1980	30543
1957	14590	1969	17251	1981	29370
1958	13829	1970	20610	1982	30078
1959	12042	1971	25035	1983	29854
1960	8227	1972	26368	1984	30679
1961	7552	1973	25794	1985	33140
1962	9997	1974	26078	1986	33719
1963	13180	1975	28117		

Source: China's Statistical Yearbook 1987, p. 178.

hogs provide 87 million metric tons of organic matter, 11.6 million metric tons of nitrogen, phosphate and potash nutrient annually [12]. Of course, not all excreta are collected and used as manure. A great proportion of nutrients, particularly nitrogen, is lost because of the processes of volatilization and leaching before collection or application. Thus the rate of utilization should be considered carefully when the total nutrients provided by hogs are estimated.

Moreover, how to prevent the loss of nitrogen and how to kill pathogenic or-

[12]Op.cit., Sun, p. 114. Han Sun estimated that 500 million hogs are fed in China each year with an annual feeding period of 8 months.

ganisms are two major problems in the handling and preserving of human and animal manures [13]. Nitrogen is unstable in human and animal manure form. In order to reduce the losses, human waste is always stored in leach-proof pits close to the field for a period of time. During the process of storage and decomposition, the temperature is high in these pits and ammonium(NH_3) is produced. Under this condition, many kinds of pathogenic organism and bacterium are killed.

During the winter months, litter is used to keep hogs warm in the sty. As the hogs tread on it, it begins to absorb liquid urine and waste. Then a slow anaerobic rotting occurs. After several weeks to a month, the manure is moved out and new litter is moved in. Generally, the manure is mixed with river mud, peat, plant ashes and human waste. It takes months for this kind of manure to decompose and become readily available manure. During the summer, the excreta is removed with water and other materials to pits outside the sty and remains there for a period of time. This method reduces the losses from volatilization because released nutrients can be built up by organic matter and be readily available over future years. Farmers have a deep appreciation of the merits of using this mixed manure in crop production. First, it is rich in nitrogen and contains higher readily available nutrients. Second, it is easy to decompose. The disadvantage of this manure is that it is very labor intensive. In addition, farmers may lose interest in the

[13]Ibid.

collection and preparation of this farm yard manure as they can purchase more chemical fertilzers.

The manure of horse, cattle and sheep are very important manure resources. It is estimated that each horse can provide approximately 94 kilograms of nitrogen, phosphorus and potassium annually [14]. Horse manure is rich in cellulose, hemi-cellulose and it is loose in texture. Cattle contribute more manure than horse do annually. The total range of cattle manure being 103 kilograms of combined nutrients, even though, it is dense and difficult to decompose. Sheep can provide 13.78 kilograms of combined nutrient annually. The total supply of manure can be significant from the large size of the sheep population (Han Sun, 1987).

2.1.2 Green Manures

The cultivation of green manure crops has been encouraged not because these crops can provide large quantities of organic fertilizer, but because they can protect the soils from heavy erosion when they are grown. At the same time, green manure crops supply fodder for livestock. Evidence also suggests that they can improve the productivity of salty and alkaline soils in northern China and the acid red soils in southern China (Sun, 1987). In 1964 green manure crops were grown on more than 5.3 million hectares of land, 1.37 times greater than the acreage in 1952 [15]. The acreage of green manure

[14] Op.cit., Kueh, p. 221.
[15] Ibid.

crops reached a peak in the 1970s when a total of 13 million hectares of land, which was approximately 13 percent of the arable land, was used to grow these crops [16]. Since then, the acreage under green manure crops has been declining gradually. The major reason is that green manure crops may compete for land with grain crops and cotton [17]. Moreover, seed shortage and constitutional change in rural areas also affect the production of green manure crops [18]. Although Chinese scientists have strongly recommended green manure crops because they have high and balanced nutrient content, in 1986 the acreage under green manure crops in various areas is reduced to only 4.42 million hectares [19]. Generally, the cultivation of green manure crops has been more popular in southern China because of favorable weather conditions such as longer growing season and higher temperatures in winter. In these southern provinces, green manure crops have been planted on fallow land and land between rows of other crops. For instance, green manure crops may be planted with the main crop simultaneously and be plowed before harvest. This method of intercropping neither reduces the sowing area of the main crop nor interferes with regular plantings (Sun, 1987). In addition, there are other intercropping systems in different areas in China.

[16]Ibid.

[17]Op.cit., Hsu, p. 55.

[18]In 1978 the government decided to break the rural management system down. Individul farmers obtained their rights to make production decisions. Without change in the common ownership, land is contracted to individul families, who can earn more if they produce more. As a result, the acreage of green manure crops has been reduced as farmers decrease their production costs.

[19]Data is from China's Statistical Yearbook 1987, p. 169.

The growing of vetch in a cotton-wheat double-cropping pattern can be observed everywhere in south China. Before the harvest of cotton in autumn, vetch seeds are planted between cotton rows. As cotton is harvested and the stalks are removed, wheat seeds are planted in the rows where cotton grew before. Then, wheat and vetch crops grow simultaneously until next spring. In May, the vetch is plowed under while green and cotton seeds are sown on the tops of the rows. The wheat and cotton grow together until the harvest of wheat. This cropping pattern does not affect the growth of both wheat and cotton crops but is more labor intensive (Sun, 1987).

2.1.3 Biogas Production

Small-scale biogas units not only provide a new energy source but also improve organic manures. Underground digesters are usually contructed with brick and cement near the house. The capacity of each digester is around 6-10 cubic meter and can supply enough biogas for a 4-6 person family [20]. Human and animal waste, crop residues, grass and leaves are used as raw materials to produce biogas which contains about 70 percent pereme methane and 30 percent carbon dioxide through the fermentation process [21].

The benefits of biogas production are numerous. First, biogas provides an efficient energy source. In China more than one-half of crop residues are burned with heating efficiency of only 10 to 15 percent while the heating

[20] Op.cit., Hsu, p. 89.
[21] Ibid., p. 88.

efficiency of biogas is 50 to 60 percent [22]. In addition, the more biogas digesters built, the more organic materials that can be recycled in the field and the less forest and grassland are destroyed. Second, biogas production provides complex manure. During the fermentative process, 40 to 50 percent of the organic carbon is converted into gases. The other nutrients remain in the sludge except for a small loss of nitrogen [23]. As a result, the sludge is richer in nitrogen, phosphorus and potassium than other manure forms. Third, the burning of biogas is cleaner and more convenient than the burning of plant residues. Thus it protects environment from pollution. Finally, the fermentative process in an underground digester also helps to control diseases [24].

In 1980, there were more than 7 million small-scale digesters throughout China. In addition, there were some 36,000 larger digesters built by communes, state farms, etc. [25].

Table B.1 and B.2 in Appendix records the results of the most recent effort to estimate the total supply of organic fertilizers in China. Kueh collected more complete and recent official statistical information than his predecessors and analyzed different resources of organic fertilizers in detail [26]. With so

[22] Op.cit., Sun, p. 122.

[23] Op.cit., Hsu, p. 89.

[24] Ibid.

[25] Ibid.

[26] Kueh employed this formula in his study: $NF = Q \times U \times (n+p+k) \times An/Ac$. Where NF is the annual total of organic fertilizers in nutrient weight from all sources; Q the gross weight of organic fertilizers; U the rate of utilization; n, p, k the nutrient coefficient for nitrogen, phosphorus and potassium, respectively; and An/Ac is the plant absorption rate

many kinds of manure involved in this estimation, different estimates may have different results. But, Kueh's estimate still showed several weaknesses. First, most of soybean cakes were used as fodder to feed livestock in northern China where soybean was a major crop. A small proportion of soybean cakes might be applied to grow water melon or other cash crops but little was used as organic fertilizer for grain crops. Second, the estimate didn't include the number of hogs which were slanghtered before the end of each year. With the enormous size of the hog population, the differences in total manure supply can be considered significant. Finally, fuel is seriouly lacking in rural areas. Therefore, about one-half to three-fourth of crop residues is burned for heating and cooking every year. There may not have a great amount of crop residues left which can be used as organic fertilizer. It is very important to pay attention to the role of organic fertilizers in agricultural production. Organic fertilizers still make up the bulk of total nutrient supply even though the process of substitution of chemical fertilizer for organic fertilizer has emerged. At the same time, the supply of organic fertilizers is constrained by the natural resources and affected by many other factors. As the demand for food, vegetable and fodder increases, the efficient use of organic fertilizers will result in high-yield, high-quality agricultural products.

for organic and chemical fertilizers, respectively.

2.2 Demand, Production and Import of Chemical Fertilizer

2.2.1 Demand for Chemical Fertilizer

The recorded performance for chemical fertilizer has been significant worldwide. According to a comprehensive estimate, 40 to 60 percent of the increase in crop yield comes from the use of chemical fertilizer [27]. From 1960 to 1977, the Food and Agricultural Organization of the United Nations allocated 100,000 field experiments to test the effect of chemical fertilizer in 40 countries. The results indicated that the most effective use of chemical fertilizer would cause an average of 67 percent increase in crop yield and each one dollar investment in the use of chemical fertilizer would yield 4.8 dollars from agricultural production [28].

In 1958 the Chinese Academy of Agricultural Science set up a national network for experimentation with chemical fertilizer. Agricultural research institutes in 25 provinces, municipalities and autonomous regions participated in these field experiments. The aim of this network was to study the effective use of chemical fertilizer for different crops such as rice, wheat and corn in different regions and on different soil types [29]. By the end of 1962, 122 field experiments had been completed (see Table 2.3). The result of the

[27] Op.cit., SICAAS, p. 8.

[28] FAO, "Fertilizer and Their Use, 1978."

[29] Leslie T.C.Kuo, Agriculture in the People's Republic of China (New York: Praeger Publishers, Inc., 1976), p. 148.

Table 2.3: The Effect of Chemical Fertilizer Use, 1958-1962

Crop	*The yield responses to different chemical fertilizers*		
	N(nitrogen)	P_2O_5(phosphate)	K_2O(potash)
	kgs	kgs	kgs
rice	15-20	8-12	2-4
wheat	10-15	5-10	no effect
corn	20-30	5-10	2-4
cotton*	8-10	– – –	– – –
rapeseed	5-6	5-8	– – –
potato	40-60	– – –	– – –

Note: The use of different chemical fertilizers was counted in nutrient weight. Each kilogram of additional use in nitrogen would increase 15-20 kilograms of rice as show in (Table 2.3). * The weight of cotton included the weight of its seed. Sources: SICAAS, Regional Differentiation of Chemical Fertilizer (Beijing: Agricultural Science and Technology Press, 1986), p. 7.

experiments indicated that the effect of nitrogen was significant on different types of soil all over the country and that the effect of phosphate was significant in south of the Yangtze River but not in north. The use of potash didn't show significant effects in most regions [30].

As may be observed from Table 2.4, the demand for nitrogen was significatly high in China because the use of nitrogen fertilizer would increase crop yield. The test result also confirmed that Chinese farmland was seriously deficient in phosphate after thousands of year's cultivation. During the period of late 1950s, most of the fertilizers used by farmers were organic fertilizers. However, the yield per unit of farmland was low because organic fertilizers

[30] SICAAS, op.cit., p. 18-22.

decompose slowly in the soil and they can hardly satisfy the demand for fertilizer when growing crops use nutrients from the soil at a concentrated rate. Although new varieties and irrigation systems played an important role in increasing crop yields in 1950s, further development of grain production had to rely on chemical fertilizer. The reasons were: first, the growing population put high pressure on agriculture for food, clothing, employment, raw materials, etc.; second, farmland was limited; third, grain production was constrained by soil deficiency in nutrients (NPK).

The second field test was conducted by the Chinese Academy of Agricultural Science in 1981. By the end of 1983, this field test had been completed in 29 provinces, municipalities and autonomous regions. The results of 829 field experiments on rice, 1,260 on wheat and 629 on corn indicated that the yield response to the use of chemical fertilizers was high. Compared with their corresponding treatments in which no chemical fertilizer was used, the yield of rice, wheat and corn increased 40.8, 56.6 and 46.1 percent, respectively(SICAAS, 1986).

When phosphate fertilizer is used, each kilogram nitrogen fertilizer would increase rice by 9.1 kilograms, wheat by 10 kilograms, corn by 13.4 kilograms and soybean by 4.3 kilograms. Compared with the first field test, the effect of nitrogen fertilizer has been reduced approximately one-half on rice, corn and cotton. The diminishing return might be explained in this way: as more and more nitrogen fertilizer was used, phosphate fertilizer became a constraint

Table 2.4: The Effect of Chemical Fertilizer Use, 1981-1983

Crop	*N(nitrogen)*			P_2O_5 *(phosphate)*		
	NOE*	Use of fertilizer	Each kg's contribution	NOE	Use of fertilizer	Each kg's contribution
		kgs/hec	kgs		kgs/hec	kgs
rice	896	126.0	9.1 ± 0.20	921	57.8	4.7 ± 0.15
wheat	1462	117.8	10.0 ± 0.17	1851	80.3	8.1 ± 0.16
corn	728	124.5	13.4 ± 0.41	1040	83.3	9.7 ± 0.30
sorghum	106	113.3	8.4 ± 0.40	129	90.8	6.4 ± 0.25
soybean	87	117.0	4.3 ± 0.42	134	93.8	2.7 ± 0.69
rapeseed	68	158.3	4.0 ± 0.45	97	66.0	6.3 ± 0.83
cotton	45	168.8	1.2 ± 0.12	97	99.0	0.7 ± 0.05
potato	16	62.3	58.1 ± 15.0	44	59.3	33.2 ± 6.90

Note: The field test was measured by: if the effect of different nitrogen fertilizer uses was tested, a fixed amount of phosphate fertilizer was applied on fields. The effect of different phosphate fertilizer uses was tested while a fixed amount of nitrogen fertilizer was used on fields. The effect of potash fertilizer was tested in the same way but both nitrogen and phosphate fertilizers were used. * NOE is number of experiments.
Source: SICAAS, "A Report of the National Network for Experimentation with Chemical Fertilizer, 1981-83," p. 17.

factor which tipped the balance of nutrient content on different types of soil. The second field test result also confirmed that the effect of nitrogen fertilizer was higher on low and middle-yield farmland [31].

[31]The field test result indicated that there was a significant correlation between the effect of chemical fertilizer and the farmland fertility. When there was no chemical fertilizer used on farmland, the different farmland fertility levels could be measured by the different yield levels. Compared with the effect of chemical fertilizer on high-yield farmland, the effect of chemical fertilizer on low and medium-yield farmland was significantly higher and the margin was 4.0 kilograms on rice, 5.0 kilograms on wheat and 5.5 kilograms on corn. For more detail, see SICAAS, Regional Differentiation of Chemical Fertilizer

Combined with nitrogen fertilizer, each kilogram phosphate fertilizer contributed to an increase of 4.7 kilograms of rice, 8.1 kilograms of wheat, 9.7 kilograms of corn and 0.7 kilograms of cotton (Table 2.4). Compared with 1961 test result, the diminishing return of phosphate fertilizer appeared in rice but not in corn and wheat. The reasons were: first, organic fertilizer no longer released enough phosphate nutrients as the yield of crops was increasing. Therefore, the effect of phosphate fertilizer was significant on both corn and wheat; second, in the 1965-1976 period, 80 percent of phosphate fertilizer was sold in 13 provinces south of the Yangtze River (SICAAS, 1986). In these provinces, the main crop was rice. As a result, phosphate content in the soil of these provinces was comparatively high.

The effect of potash fertilizer use was significant. Each kilogram of additional potash fertilizer would increase rice by 4.9 kilograms, wheat by 2.1 kilograms, corn by 1.6 kilograms and cotton by 0.95 kilograms (Table 2.5). Field test results also indicated that the effect of potash has increased significantly in provinces south of the Yangtze River. As hybrid rice and high-yield rice varieties have spread, more and more nitrogen and phosphate fertilizers but less potash fertilizer are used. Therefore, the potash content can hardly maintain its balance in these provinces.

Overall, the demand for chemical fertilizer has grown at a faster rate than the supply because both marginal and average rates of returns to the applica-

(Beijing: Agricultural Science and Technology Press, 1986) p.18.

Table 2.5: The Effect of Potash Fertilizer Use, 1981-1983

Crop	Potash(K_2O)		
	Number of experiments	Application of potash(kgs/hec)	The effect of per kg potash
rice	875	87.0	4.9 ± 0.16
wheat	678	85.5	2.1 ± 0.23
corn	314	97.5	1.6 ± 0.67
sorghum	11	92.3	2.9 ± 0.45
soybean	64	120.0	1.5 ± 0.07
rapeseed	39	88.4	0.63 ± 0.08
cotton	57	135.0	0.95 ± 0.08
potato	3	90.0	10.3 ± 5.00

Source: same as Table 2.2.

tion of fertilizers (chemical and organic combined) are comparatively high in present-day China (Kueh, 1985). Therefore, there is still substantial room for expanded application of chemical fertilizers when the application of organic fertilizer is constrained by the natural resource supply. From 1952 to 1986, grain output grew at an annual rate of 2.59 percent while the population growth rate averaged 1.81 percent [32]. At the same period, the application of chemical fertilizers grew at 17.6 percent annually [33] and total grain output increased from 163.92 to 391.51 million tons under the basically constant size of sown area [34]. It can be observed that grain output per sown hectare also increased dramatically from 1,160.4 kilograms in 1952 to 2,715 kilograms in

[32]Calculated from data in China's Statistical Yearbook 1984-1987.
[33]Calculated from data in Table 2.6.
[34]See Table B.3 in Appendix.

1986 [35]. But per capita grain availability grew only from 285.2 kilograms in 1952 to 370.3 kilograms in 1986 [36], a very low annual growth rate of 0.77 percent [37]. These few basic statistics illustrate that increased application of chemical fertilizer has been very important producing enough food for more than 1 billion people.

2.2.2 Production and Application of Fertilizer

The production and application of chemical fertilizer seems to have improved in the past three decades. Table 2.6 records annual production and application of chemical fertilizers in nutrient weight. The production of chemical fertilizer in 1952 was 39,000 tons and the use of chemical fertilizer was 78,000 tons. The use of chemical fertilizer soon after the Communist takeover was insignificant in China compared with its cultivated areas of 100 million hectares. Moreover, the quantity of chemical fertilizers demanded was higher than the quantity supplied and China had to import chemical fertilizers to satisfy its demand.

If historical development can be divided into 7 periods based on SSB's division of the 33 years, the trend of the production and application can be shown. Following are the seven periods:

1953-1957 The First Five-Year Plan period.

[35] Caculated from data in China's Statistical Yearbook 1984, p. 137 and p. 141 and China's Statistical Yearbook 1987, p. 164 and p. 169.

[36] Ibid.,1987, p. 89.

[37] Calculated from data in China's Statistical Yearbook 1984-1987.

1958-1962 The Second Five-Year Plan period.

1963-1965 Post Great Leap Forward recovery period.

1966-1970 The Third Five-Year Plan period.

1970-1975 The Fourth Five-Year Plan period.

1976-1980 The Fifth Five-Year Plan period.

1981-1985 The Sixth Five-Year Plan period.

Table 2.7 lists the five-year average growth rate for both production and application of chemical fertilizers in China. Production growth within each period ranged from 0.3 to 63 percent. In 1953-1957 and 1963-1965 periods, the growth rates were significantly higher: 32 percent per annum in the first period and 63 percent in the second period. The rapid increase in production was due to the low base level in 1953-1957 period and the first-stage installation of the Wu Ching Chemical Plant, the second-stage installation of the Kirin Chemical Fertilizer Plant, and the trial production of the Canton Nitrogen Fertilizer Plant in 1963-1965 period (Kuo,1976). As may be observed, the lowest growth rate was 0.3 percent in 1966-1970 period. In 1966 the total output of chemical fertilizer was 2.4 million tons when the Cultural Revolution was instigated by Mao Tse-tung with the aim of purging his political opponents. As many workers participated in the "Revolution", a large portion of chemical fertilizer plants was shut down. Consequently, the output of chemical fertilizer declined to 1.64 million tons in 1967 and 1.10 million tons in 1968. Not until 1970 did the production of chemical fertilizer recover from the effects of this man-made disaster. From 1952 to 1986, the growth rate of chemical fertilizer production averaged 18.9 percent [38], a considerably high level over a prolonged time period. In fact, chemical fertilizer production is the only item, except military goods, that did not show any decline in production in 35 years when 1966-69 period is not counted.

There are several reasons that chemical fertilizer production is very important in agriculture. First, Chinese farmers have used organic fertilizers for sustaining production and maintaining soil fertility for over three thousand years. A massive use of organic fertilizers has retarded the depletion process for other nutrients, leaving nitrogen as the deficient nutrient in most areas (Stone,1986). Second, fuel is critical in rural areas, about one-half to three-fourths of the crop residue is burned for cooking and heating despite their low heating efficiency of only 10 to 15 percent [39]. As a result, when the ash is returned to the soil, nitrogen is completely lost. Third, nitrogen is unstable in human and animal manure form since it may disintegrate or evaporate as a compound matter. Fourth, the deficiency in phosphate, potash and other trace elements has been increasing. Finally, the population in China has exerted a great pressure on agriculture to produce enough food. Therefore, the government has invested a huge amount of capital to increase chemical fertilizer production capacity since 1949.

The growth rates of fertilizer application were ranged from 3.6 to 48 per-

[38]Calculated from data in China's Statistical Yearbook 1987.
[39]Op.cit., Sun, p. 122.

cent per annum during the seven time periods. Because of the low base application levels, the impact of rapid development in the earliest period can be largely discounted (Stone, 1986). In the 1966-1969 period, the production of chemical fertilizer decreased but the application of chemical fertilizer remained comparatively stable. The reason was that China imported a considerable quantity of chemical fertilizer to fulfil its demand.

The application of chemical fertilizer in China had risen from 0.55 kilograms of pure nutrients per hectare of cultivated land in 1952 to 2.4 kilograms in 1957, 4.5 kilograms in 1970, 33.3 kilograms in 1975, 86 kilograms in 1980 and 133.8 kilograms in 1986 [40]. From 1952 to 1986, the application of chemical fertilizer increased at an annual rate of 17.6 percent [41].

In the future, chemical fertilizer will play a more and more important role in agricultural production. First, farmers have obtained benefits from using chemical fertilizer on grain crops. At the same time, they have increased the application of chemical fertilizer on cash crops because more benefits can be achieved. As a result, the demand for chemical fertilizer will continuously increase. Second, the use of organic fertilizers is reduced because the

[40] Robert Hsu points out that the application of chemical fertilizer per hectare of cropland increased from an annual average of 13.3 kilogram nutrients in 1961-1965 to 45.5 kilograms in 1972, 74.3 kilograms in 1977, 109.2 kilograms in 1979 and 201 kilograms in 1986* while the world average was 27.9 kilograms in 1961-1965, 54.3 kilograms in 1972, 68 kilograms in 1977, 77.1 kilograms in 1979 and 94.5 kilograms in 1986. The application of chemical fertilizers per hectare of cropland exceeded the world average in 1977 and the growth rate of chemical fertilizer application in China was higher than that in the rest of the world. For more detail, see Robert C. Hsu, Food for One Billion (Colorado: Westview Press Inc., 1982), p. 56. * 1986 figures come from SICAAS.

[41] Calculated from the data appearing in Table 2.6.

collection and preparation of those fertilizers is labor-intensive. Under the new production responsibility contract system, farm labor is migrating to other industries. Thus, farmers are willing to purchase chemical fertilizer. To compensate nutrients in different types of soils, the more use of chemical fertilizer is necessary. Third, more chemical fertilizer has been used for feed crops, forestry and so on. As a result, the positive growth rate of chemical fertilizer application must remain.

2.2.3 Chemical Fertilizer Imports

China has imported chemical fertilizers since 1905 [42]. From 1905 to 1949, chemical fertilizer imports totalled less than 3 million tons in standard weight [43]. In order to maintain a desired rate of increase in crop yield and output to satisfy the demand from the ever-increasing population, China has increased its chemical fertilizer imports, except for a few years, since 1949 under the condition that domestic production is far from being adequate.

Before the large-scale construction of the fertilizer industry at home was underway, imports played a key role in increasing foodgrain production. In 1954, 129,700 tons chemical fertilizers in nutrient weight [44] was imported and the number reached 1.11 million tons in 1969 at a cost of U.S. $180 million [45]. In 1970 China imported 8 million tons of chemical fertilizers

[42] Op.cit., SICAAS, p. 2.

[43] Op.cit., Kuo, p. 154.

[44] It is assumed in this study that all chemical fertilizers consist of 20 percent nutrient weight.

[45] Op.cit., SICAAS, p. 3.

in standard weight, accounting for 20 percent of the world's total fertilizer imports, and became the world's largest fertilizer importer (Kuo,1976). In 1983 it imported 3.04 million tons of chemical fertilizer in nutrient weight at a cost of U.S. $1.2 billion and another 1 billion yuan for domestic subsidies when they were sold in the rural markets [46]. The largest fertilizer imports were 3.85 million tons in 1984 (Table 2.8).

The imports of chemical fertilizer also provided a solution to the fertilizer problem in another sense. China could not produce certain types of fertilizers as its chemical fertilizer industry began to develop in the 1950s. To maintain the balanced nutrient content in the soil, different varieties of chemical fertilizers were imported as complements to domestic production.

During the First and Second Five-Year Plans (1953-1962), two large-scale nitrogen fertilizer plants were expanded and many small-scale fertilizer plants were built. In the 1970s, China imported 13 large-scale complexes. As a result, chemical fertilizer production increased rapidly. In 1954, 81 percent chemical fertilizers applied in China came from imports but this proportion was reduced to only 13 percent in 1986. During the same period (1952-86), the quantities of imports increased steadily because of the rapidly growing demand.

Nitrogen fertilizers have been the largest item among the imported fertilizers. Ammonium sulfate and calcium ammonium nitrate were two largest

[46]Ibid.

items imported in the 1960s and the 1970s (Kuo,1976). Imports of urea have increased steadily since the 1970s. Recently the imports of phosphate, potash and compound fertilizers have increased considerably (SICAAS,1986).

Japan has become an important chemical fertilizer supplier to China. In 1968 China imported 2.46 million tons ammonium sulfate in standard weight with a cost of U.S. $74 million. One year later, the total imports increased to 2.85 million tons at a cost of U.S. $80.8 million. In 1970 China imported 5.47 million tons of chemical fertilizer from Japan. It is understandable that China is willing to purchase chemical fertilizers from Japan. First, the price of Japanese fertilizers is lower than that of European fertilizers. Second, Japan can use small ships to carry fertilizers to China, which reduces the shipping and handling costs and can deliver fertilizers to any port without delay (Kuo, 1976). The Soviet Union and Canada also play an important role in suppplying China with chemical fertilizers.

This chapter had provided the historical background of China's utilization of both organic and chemical fertilizer and China's imports. Although China has made the most significant progress in the production and application of chemical fertilizer in the world, there are still several serious problems in this sector.

Table 2.6: The Production and Application of Fertilizer, 1952-86

Year	Production of fertilizer (10,000 tons)	Application of fertilizer (10,000 tons)	Year	Production of fertilizer (10,000 tons)	Application of fertilizer (10,000 tons)
1952	3.9	7.8	1970	243.5	351.2
1953	5.0	11.6	1971	299.4	410.4
1954	6.7	16.0	1972	370.1	455.9
1955	7.9	24.4	1973	459.2	502.8
1956	11.1	33.3	1974	422.2	476.6
1957	15.1	37.3	1975	524.7	489.0
1958	19.4	54.6	1976	524.7	528.8
1959	26.6	53.8	1977	723.8	595.9
1960	40.5	66.2	1978	869.3	844.0
1961	29.7	44.8	1979	1065.4	1086.0
1962	46.4	63.0	1980	1232.1	1269.4
1963	64.8	104.3	1981	1239.0	1334.9
1964	100.8	129.0	1982	1278.1	1513.4
1965	172.6	194.2	1983	1378.9	1659.8
1966	240.9	265.5	1984	1460.2	1739.8
1967	164.1	266.1	1985	1332.2	1775.8
1968	110.9	199.5	1986	1395.7	1930.6
1969	174.9	273.1			

Note: Standard weight denotes that chemical fertilizer consisting of 21 percent nitrogen, 18 percent phosphate and 25 percent potash. It is assumed that all chemical fertilizers consist of 20 percent nutrient weight.
Source: The data of column 2 and 3 are from SICAAS, p. 6–7. Column 4 is from SSB, China's Statistical Yearbook 1984, p. 410 and China's Statistical Yearbook 1987, p. 601.

Table 2.7: The Growth Rate of Chemical Fertilizer, 1953-1985

Period	Growth rate of fertilizer production	Growth rate of fertilizer application	Growth rate of fertilizer imports
	(percentage)	(percentage)	(percentage)
1953 – 1957	32.0	48.0	54.8
1958 – 1962	24.0	3.6	10.8
1963 – 1965	63.0	36.0	3.9
1966 – 1970	0.3	7.2	19.5
1971 – 1975	15.0	4.5	-6.3
1976 – 1980	24.0	24.0	21.5
1981 – 1985	1.6	7.4	-4.9

Note: The growth rates were calculated from the data appearing in following books: SSB, China's Statistical Yearbook 1984 and China's Statistical Yearbook 1987 and SICAAS, Regional Differentiation of Chemical Fertilizer. Source: SICAAS, Regional Differentiation of Chemical Fertilizer, Table 1-1, p. 6 and SSB, China's Statistical Yearbook 1984-1987.

Table 2.8: Chemical Fertilizer Imports, 1952-1986

Year	Imports (10,000 tons)	Proportions imported(%)	Year	Imports (10,000 tons)	Proportions imported(%)
1952	4.23	54	1970	128.37	36
1953	7.20	62	1971	128.08	51
1954	12.97	81	1972	135.24	30
1955	16.34	67	1973	125.66	25
1956	26.73	80	1974	102.04	21
1957	24.33	64	1975	98.70	20
1958	39.34	72	1976	91.76	17
1959	30.34	56	1977	127.91	21
1960	25.01	38	1978	146.67	17
1961	26.65	59	1979	167.89	15
1962	24.81	39	1980	200.35	16
1963	50.65	49	1981	186.13	14
1964	36.16	28	1982	222.16	15
1965	54.70	28	1983	303.85	18
1966	62.97	24	1984	385.50	22
1967	97.60	37	1985	256.70	14
1968	104.14	52	1986	241.50	13
1969	111.05	41			

Note: It is assumed that all chemical fertilizers consist of 20 percent nutrient weight. "Proportion imported" figures are calculated by dividing current year nutrient weight imports by current year weight application data and may not reflect the exact proportion of imported products among applied fertilizers.

Source: China's Statistical Yearbook 1984, p. 401 and China's Statistical Yearbook 1987, p. 601.

Chapter 3

Theoretical Framework of Demand Functions for Chemical Fertilizer (NPK) in China

This chapter provides the discussion of the methodology used in the empirical analysis of the study. The discussion includes five sections, namely: theoretical framework, specification of demand functions, methods of analysis, hypotheses and assumptions, and exogenous variables. In addition, a basic regression model is employed for time series estimate. Unfortunately, it is impossible to analyze the demand for chemical fertilizers in different regions because of the scarcity of detailed information.

3.1 Theoretical Framework

According to traditional theory of the firm, the decision maker always prefers to maximize profits when input/output and price ratios are known and capital is unlimited. At the same time, it is also assumed that individual decisions have no influence on price under a purely competitive market [1].

For purpose of simplicity in presentaton, it is assumed that only two inputs are included in the production of crop Y: land (X_1) and chemical fertiliizer (X_2). Equaton (3.1) is a production function. Profit function can be defined in (3.2) from equation (3.1).

$$Y = f(X_1, X_2) \tag{3.1}$$

$$\pi = f(X_1, X_2)P_y - P_1X_1 - P_2X_2 \tag{3.2}$$

whereP_y, P_1 and P_2 are prices of crop, land and fertilizer, respectively. Gross revenue is obtained when Y is multiplied by P_y and the total cost is defined as the sum of P_1 multiplied by X_1 and P_2 multiplied by X_2.

Profit is maximized when all resources are used at levels that their marginal return is zero:

$$\frac{\partial \pi}{\partial X_1} = \frac{\partial Y}{\partial X_1}P_y - P_1 = 0 \tag{3.3}$$

[1]E.O. Heady and L.G. Tweeten, Resource Demand and Structure of the Agricultural Industry (Iowa: Iowa State University Press, 1963), p. 42.

$$\frac{\partial \pi}{\partial X_2} = \frac{\partial Y}{\partial X_2} P_y - P_2 = 0 \tag{3.4}$$

If above two equations are divided by P_y, two more equations can be obtained:

$$\frac{\partial Y}{\partial X_1} = \frac{P_1}{P_y} \tag{3.5}$$

$$\frac{\partial Y}{\partial X_2} = \frac{P_2}{P_y} \tag{3.6}$$

Equation (3.5) and (3.6) indicate that the marginal product must equate the inverse price ratio when the profit maximizing condition is achieved.

From the above two equations, equation (3.7) is derived:

$$\frac{dX_1}{dX_2} = \frac{P_2}{P_1} \tag{3.7}$$

which indicates that the marginal rate of substitution of one input for another equated to the inverse price ratio of the two inputs.

When a Cobb-Douglas production function is chosen, there are:

$$Y = aX_1^{b_1} X_2^{b_2} \tag{3.8}$$

$$\frac{dX_1}{dX_2} = \frac{b_2 X_1}{b_1 X_2} \tag{3.9}$$

$$X_1 = b_1 b_2^{-1} P_1^{-1} P_2 X_2 \tag{3.10}$$

The assumed production function form is (3.8), the corresponding marginal rate of substitution is (3.9) and the isocline equation is (3.10) [2].

X_1 in (3.10) is defined as a function of several factors and X_2. The producton functon can be redefined when (3.10) substitutes for X_1 in (3.8).

$$Y = a{b_1}^{b_1}{b_2}^{-b_1}{P_1}^{-b_1}{P_2}^{b_1}{X_2}^{b_1+b_2} \tag{3.11}$$

Multiplying by P_y, the price of crops, the total value of crop TVP is obtained. As a result, the marginal value of the fertilizer is derived as the derivative of TVP with respect to X_2 in (3.12).

$$\frac{dTVP}{dX_2} = (b_1 + b_2)a{b_1}^{b_1}{b_2}^{-b_1}{P_1}^{-b_1}{P_2}^{b_1}{X_2}^{b_1+b_2-1}P_y \tag{3.12}$$

[2]This equation is derived from equation(3.2) when the assumption is that all resources are used at levels that their marginal return is equal to zero. Profit function is known as show:

$$\pi = aP_yX_1^{b_1}X_2^{b_2} - P_1X_1 - P_2X_2$$

$$\frac{\partial \pi}{\partial X_1} = ab_1P_y{X_1}^{b_1-1}{X_2}^{b_2} - P_1 = 0$$

$$\frac{\partial \pi}{\partial X_2} = ab_2P_y{X_1}^{b_1}{X_2}^{b_2-1} - P_2 = 0$$

$$\frac{dX_1}{dX_2} = \frac{ab_2P_y{X_1}^{b_1}{X_2}^{b_2-1}}{ab_1P_y{X_1}^{b_1-1}{X_2}^{b_2}} = \frac{P_2}{P_1}$$

$$X_1 = b_1{b_2}^{-1}{P_1}^{-1}P_2X_2$$

Where X_1 is defined as a function of the coefficients (b_1 and b_2), the prices of inputs and X_2.

To satisfy the profit maximizing use of the resource, setting (3.12) to equal the input price P_2 and reranging this equation:

$$X_2 = [(b_1 + b_2)ab_1{}^{b_1}b_2{}^{-b_1}P_1{}^{-b_1}P_2{}^{b_1-1}P_y]^{\frac{1}{1-b_1-b_2}} \tag{3.13}$$

When land is fixed, there is another equation [3]:

$$X_2 = [ab_2X_1{}^{b_1}P_2{}^{-1}P_y]^{\frac{1}{1-b_2}} \tag{3.14}$$

From equation (3.14) the demand function is able to be expressed as a function of the crop/fertilizer price ratio and other fixed factors:

$$FertilizerDemand(X_2) = f(\frac{P_y}{P_2}, X_1) \tag{3.15}$$

3.2 A Specification of Important Variables

A specification of several important variables which appear in demand functions is needed. The following are these variables:

[3]This equation is derived from equation (3.4) when land is assumed fixed:

$$\frac{\partial\pi}{\partial X_2} = ab_2P_yX_1{}^{b_1}X_2{}^{b_2-1} - P_2 = 0$$

$$X_2{}^{b_2-1} = a^{-1}b_2{}^{-1}X_1{}^{-b_1}P_2P_y{}^{-1}$$

$$X_2 = [ab_2X_1{}^{b_1}P_2{}^{-1}P_y]^{\frac{1}{1-b_2}}$$

where X_2 is defined as a function of the coefficient (b_2), constant term a, the prices of output and X_2

F_t^* = the expected total national consumption of chemical fertilizer by Chinese farmers in the current year and measured in thousands of tons.

F_1 = the index of total fertilizer consumption in China.

F_t = the actual level of fertilizer consumption by farmers in the current year.

F_{t-1} = the actual level of fertilizer consumption by farmers in the previous year.

F_p = the fertilizer price index deflated by the input sales price index for the current year (1952 used as the base year).

IN_{t-1} = the lagged farm income index deflated by the general wholesale price index.

T_t = time trend variable which indicates technological progress.

G_p = the grain price index deflated by the general wholesale price index for the current year.

OF_t = the actual level of organic fertilizer used by farmers in the current year and measured in 10 thousands of tons.

RA_t = the fertilizer/grain price ratio in the current year.

Land = the total sown hectares in China.

U = a random residual.

With these variables used, demand functions for fertilizer are estimated. All prices are deflated by the indices of corresponding item. The algebraic form of these demand functions is a logarithm form.

3.3 Methods of Analysis

This section includes a short-run and a long-run demand function estimated for fertilizer in China, with purchases measured in thousands of tons of all fertilizer purchased in nutrient weight.

Based on the deflated fertilizer price index and grain price index as specified in 3.2, the fertilizer/grain price ratio can be calculated by dividing deflated fertilizer price by deflated grain price. With the help of regression models, how much of the change in fertilizer use is attributable to change in each of the explanatory variables is investigated. At the same time, the Ordinary Least Squares (OLS) method is used.

Nerlove points out that expected product prices may depend, to a limited extent, on last year's prices. He proposes that a simple model representing expected price as a weighted moving average of past prices, where the annual weights decline over time. Because fertilizer price is controlled by the government in China, it is assumed that the quantity of fertilizer demanded is based on fertilizer/grain price ratio in the current year t in this study.

One short-run demand model is specified including variables for fertilizer/grain price ratio, one year lagged farm income and time. The equation (3.16) is a logarithmic form:

$$\log F_t = \log a + b_1 \log RA_t + b_2 \log IN_{t-1} + b_3 \log T_t + \log U \qquad (3.16)$$

where b_1, b_2, b_3 are regression coefficients.

Similarly, Nerlove's expectation model can be constructed and is shown in the following equation (3.17) at logarithmic form:

$$\log F_t^* = \log a + b_1 \log RA_t + b_2 \log IN_{t-1} + b_3 \log T_t + \log U \qquad (3.17)$$

where F_t^* is the expected fertilizer consumption in the current year.

The adjustment model is derived as it is associated with equation (3.17):

$$\log F_t - \log F_{t-1} = B(\log F_t^* - \log F_{t-1}) \qquad (3.18)$$

where F_t is the actual quantity of fertilizer consumption in the current year, F_{t-1} is the actual quantity of fertilizer consumption in the previous year, F_t^* is expected level of fertilizer consumption in the current year and B is an adjustment coefficient which indicates that farmers adjust their fertilizer use when the changes in effect of fertilizer/grain price ratio, farm income and technological progress take place. The basic idea of this equation is that this year's actual fertilizer use (F_t) will differ from last year's use (F_{t-1}) by an amount of B times the difference between the expected consumption in the current year and the actual consumption in the previous year. Substituting equation (3.17) for F_t^* into (3.18) results in equation (3.19):

$$\log F_t = B(\log a + b_1 \log RA_t + b_2 \log IN_{t-1} + b_3 \log T_t) + (1 - B) \log F_{t-1} + B \log U \qquad (3.19)$$

where Bb_i is the short-run elasticity for a particular variable, and b_i is the long-run elasticity for corresponding variable. The long-run elasticity can be found by dividing the least-square coefficients Bb_i by the adjustment coefficient B. If B is small (λ is large), the long-run elasticity is much greater than the short-run elasticity. A large value of B means that most of the adjustment is made in the first period and the long-run elasticity for a particular variable is only slightly larger than the short-run elasticity for the same variable. In this model $1 - B$ is computed as a regression coefficient for the variable F_{t-1}.

With knowledge that $1 - B = \lambda$, the adjustment coefficient can be computed as $B = 1 - \lambda$. From equation (3.19) it is apparent that when B is zero, adjustments are never made and the demand for fertilizer in the current year is equal to that of the previous year. If B equals 1, all adjustments are made in the current year and current demand for fertilizer is not directly linked to the value of demand for fertilizer in the previous year.

The main difference between equation (3.16) and (3.19) is that a lagged variable for fertilizer consumption is added.

3.4 Hypotheses and Assumptions

To estimate demand functions for fertilizers, several hypotheses and assumptions are needed to be set up in this analysis. Following are these hypotheses and assumptions:

1. Changes in chemical fertilizer price cause the changes in demand. Increases in fertilizer price result in decreases in demand for fertilizer or otherwise.

2. Changes in demand for fertilizers are responsive to changes in total farm income. The growth of demand for fertilizers can be partly explained by the increases in farmers' income.

3. Changes in demand for fertilizers are also responsive to changes in grain price. These two items move simultaneously to the same direction.

4. Changes in technical progress cause the increase in demand for fertilizer. Therefore, increases in farmers' knowledge and their managerial skills can lead to increases in fertilizer consumption.

These hypotheses are empirically testable and are established under the following assumptions:

1. Demand functions for fertilizers are Cobb-Douglas type. This indicates that the demand functions are log-linear.

2. The returns from chemical fertilizer use are constant.

3. The application of organic fertilizers may affect the demand for chemical fertilizers.

4. Funds available for purchase of fertilizer do not limit such purchase.

3.5 Data and Exogenous Variables

Data used in this study are mostly from SSB sources for the years 1952 through 1986. Since time series data are available only on a national basis, it is impossible to estimate the regional or provincial demand functions for fertilizers. Fortunately, Soil Institute, the Chinese Academy of Agricultural Science released the data of both production and application of chemical fertilizers from 1952 to 1986 while SSB only offered several years' application data before 1978. However, data in this study are more accurate compared with those of others because those authors had to estimate their own data when there were no available official statistical information. As a result, an attempt is made to eliminate the uncertainties of data series surrounding the previous studies of demand for fertilizer in China.

One of the greatest increases in farm input demand since 1949 has been for chemical fertilizer. From 1952 to 1986, total inputs of chemical fertilzer increased by 248 times [4]. Hence, chemical fertilizers have made a great contribution to maitain an expected rate of increase in crop yield and output to cope with increased demand for food from an ever-increasing population. In order to analyze the demand functions for fertilizer, several factors which affect the demand for fertilizer use need to be discussed in detail. The main factors have been the favorable price of fertilizer, the favorable fertilizer/grain price ratio, the fertilizer/raw material price ratio, increased knowledge and

[4] Calculated from data in Table 2.6.

improved production skills of farmers, increased productivity of fertilizer industry, the use of organic fertilizers, the efficient use of chemical fertilizer and a favorable income position of farmers while population and land limitation are excluded.

The real or effective price of fertilizer has been lowered through several developments in the last three and a half decades. One of such developments has been research by many state-run institutes and universities on the new technology of fertilizer production. For instance, a new process for producing ammonium bicarbonate containing 17.5 percent nitrogen was developed by Hou Tepang in 1962, which improved the efficiency of small-scale nitrogen fertillizer plants and resulted in high production capacity. At the same time, many modern large-scale fertilizer plants have been constructed in different regions. As a result, the productivity of fertilizer industry has been rising while the production costs have been reducing. In addition, the government tightly controls the price of fertilizer for eliminating price fluctuations. In a direct economic sense, farmers gain the benefits from the use of chemical fertilizers even though a more rapid decline in marginal response rate occurs in high-yield areas [5]. Along with these developments, the fertilizer industry has expanded in competition. Many small-scale fertilizer plants have been closed or merged with others because of the inefficient use of raw materials, the high production cost and the high price. The growth in competition

[5]Farmers still benefit from the use of chemical fertilizers because the achievements can cover the costs.

under the central planning system has played an important role in lowering the price of fertilizer.

Table 3.1 shows the fertilizer/grain price ratio in the period of 1952-86. The ratio declined from 2.67 in 1952 to 0.82 in 1986. It should also be noticed that, in addition to the Great Leap Forward period, the application of fertilizers continued to increase even when the fertilizer/grain price ratio

Table 3.1: Fertilizer/grain Price Ratio,1952-1986

Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio
1952	2.67	1961	1.27	1970	0.95	1979	0.71
1953	2.32	1962	1.26	1971	0.88	1980	0.66
1954	2.11	1963	1.18	1972	0.87	1981	0.64
1955	2.17	1964	1.05	1973	0.87	1982	0.66
1956	2.13	1965	1.05	1974	0.90	1983	0.66
1957	1.98	1966	1.02	1975	0.88	1984	0.90
1958	1.79	1967	0.94	1976	0.92	1985	0.89
1959	1.65	1968	0.95	1977	0.87	1986	0.82
1960	1.59	1969	0.95	1978	0.88		

Note: calculated from data in China's Statistical Yearbook.
Sources: China's Statistical Yearbook 1985-1987.

began to level out or increase in several periods from 1952 to 1986. This phenomenon can be explained in this way: not only the fertilizer /grain price ratio but other factors determine the fertilizer consumption levels. If only this ratio determines the fertilizer inputs with or without a distributed lag, farmers would adjust their fertilizer inputs according to the fluctuations of this ratio. Moreover, the favorable fertilizer/grain price ratio tended to encourage farmers to increase their fertilizer inputs.

Unfortunately, there is no available information about the fertilizer/raw material price ratio in fertilizer industry. In order to maintain a desired rate of this ratio, the government may either adjust the rate by changing raw material price or subsidize the fertilizer plants under the central planning system.

It is likely, however, that the demand for fertilizers can be determined by total farm incomes from crops and livestock. In comparatively developed areas, farmers tend to purchase more chemical fertilizers [6] because fertilizer has been the major reason for increases in yield. It can be observed from Table 3.2 that farm income increased from 28.7 to 262.6 billion yuan in 1952-86 period. During the period of 1958-60, farm income declined from 36.7 to 32.4 billion yuan (1952 price) due to the failure of the agricultural policy and natural disasters. Then, it showed a tendency to increase continuously.

Technological change has affected the demand for fertilizer in China since 1952. Because of the pioneering work of Schultz, the importance of education in productivity growth is by now fairly well recognized [7]. Increase in stock of human capital due to schooling will cause an increase in technological knowledge of farmers and the improvement of managerial skills of operators.

[6] The quantities of chemical fertilizer use in several comparatively rich provinces is high: the annual consumption of fertilizer is 1.81 million tons in Shandong, 1.49 million tons in Jiangsu, more than 1 million tons in Sichuan, Henan, Hunan, Guangdong and Hebei.

[7] Gian S. Sahota, Fertilizer in Economic Development (New York: Frederick A. Praeger Publishers, 1968) p. 165.

Table 3.2: Farm Income in China, 1952-86

Year	Income (billion yuan)	Year	Income (billion yuan)	Year	Income (billion yuan)	Year	Income (billion yuan)
1952	28.7	1961	29.3	1970	75.5	1979	126.6
1953	30.9	1962	32.3	1971	78.0	1980	152.2
1954	33.3	1963	46.6	1972	80.2	1981	178.5
1955	36.4	1964	54.2	1973	82.4	1982	217.1
1956	39.1	1965	63.8	1974	84.4	1983	242.8
1957	39.9	1966	66.0	1975	86.0	1984	250.4
1958	40.3	1967	68.1	1976	87.5	1985	263.6
1959	36.7	1968	70.5	1977	96.6	1986	262.6
1960	32.4	1969	72.9	1978	105.6	1987	

Note: per capita farm income data is from C.A. Carter and F.N. Zhong, China's Grain Production and Trade (Colorado: Westview Press, 1988) p. 90. These figures are multiplied by the numbers of rural population to get total farm income.
Source: China's Statistical Yearbook 1985-1987.

Moreover, technological change is in part the result of processing innovations and other internal improvements in chemical fertilizer industry. As more research work is conducted by state-run institutes and universities, mineral deposits are explored and new methods in production are applied. The more soil information is gathered from field tests and the more efficient methods of fertilizer use are expanded, the greater use of fertilizer is expected in those low-yield areas. In addition, improved seed varieties, better irrigation systems and other new practices also tend to increase the use of fertilizer. Unfortunately, it is very hard to isolate quantitatively the effect, either direct or indirect, of each factor. Thus, it is necessary to use a time variable to express those effects (Heady, 1963).

The application of organic fertilizers is important for both crop production and soil fertility. According to a field test, which was conducted by the Zheijiang Academy of Agricultural Science, the loss of nitrogen increased from 15.2 to 20 percent when the proportion of organic matter applied in the field was reduced from 60 to 20 percent under the same condition of treatment [8]. However, the use of organic fertilizers is one of the best ways to complement soil nutrients. Until present, organic fertilizers supply most of potash nutrient that crops need [9]. Moreover, organic fertilizer also adds to the humus content of the soil, which, in turn, improves the soil's physical and chemical properties. Other benefits from the use of organic fertilizers are improvements in aeration, percolation, absorption, buffering capacities and desirable soil microbiological effects [10].

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[8]Op.cit., MCI, p. 23.
[9]Ibid.
[10]Op.cit., Sun, p. 113.

Chapter 4

An Evaluation and Interpretation of the Empirical Results for the National Demand Functions for Fertilizer

This chapter provides and evaluates the empirical results for the demand functions of total chemical fertilizer in China. All the empirical results derived by the ordinary least squares (OLS) for both short-run and long-run models are presented in Table 4.1. Following this, the analysis of the future demand for fertilizer is presented.

4.1 Evaluation of the Results of Short-run Models

The estimated results of a short-run model for the three-variable function for the time period 1952-86 are presented in equation (4.1), which is derived from previous equation (3.16):

$$\widehat{logF_t} = -2.49 - 0.77^{**} \log RA_t + 1.05^{**} \log IN_{t-1} + 0.96^{**} \log T_t \qquad (4.1)$$

The mean regression coefficient (elasticity) for fertilizer/grain price ratio (RA) was -0.77 in equation (4.1). This coefficient indicates that a 10 percent decrease in fertilizer/grain price ratio, ceteris paribus, the quantity of fertilizer demand is predicted to increase about 7.7 percent. The mean regression coefficient (elasticity) for lagged farm income (IN) is 1.05, which means that a 10 percent increase in farm income will result in an increase of fertilizer consumption by 10.5 percent. Both of these two coefficients are statistically significant at the 1 percent level. Also, the mean coefficient (elasticity) for time (T) in equation (4.1) is significant at the 1 percent significance level. This elasticity indicates that there has been a significantly upward shift of the demand function for chemical fertilizer during the period analyzed.

The coefficient of determination R^2 is 0.99, suggesting that 99 percent of the variation in the fertilizer use is explained by these three variables. At the same time, the computed F-value is 915.6, which is much greater than the critical value and indicates that this short-run model is statistically acceptable.

According to the regression results represented in equation (4.1), all coefficients (elasticities) have signs consistent with hypotheses. At the same time, the t-test is performed to determine whether the estimated coefficients are statistically significant [1].

The higher simple correlation coefficient between each pair of independent variables indicates the problem of multicollinearity. In this analysis, the correlation coefficient between technological progress and farm income is 0.89, indicating that there has been a significant upward shift of both farm income and technology in the period analyzed. This higher correlation would probably provide a better forecasting performance if past and current tendencies of farm income and technology contiune.

Glejser's method is used in this estimate to test heteroscedasticity problem. A new data set is created to regress the residuls on the explanatory variables used in the original model. The test result indicates that those coefficients are not found significantly different fron zero, predicting that there is no heteroscedasticity in this short-run model.

It should be noticed that Durbin-Watson test value in this estimate is 1.63, indicating that the null hypothesis is accepted and there is no autocorrelation because of $d_U < d^* < (4 - d_U)$.

[1] Levels of significance: * = 5 percent and ** = 1 percent.

In China farmers make their fertilizer purchase decisions according not only to the fertilizer price, but also to the aggregate rates of response of grain output to incremental applications of various fertilizers. For instance, in 1986 fertilizer price was 0.33 yuan per kilogram while grain price was 0.25 yuan per kilogram [2]. If the rate of response of grain output to the use of fertilizer is more than 1.32, there is no doubt that farmers can obtain profits from the use of fertilizers. At present, the rate of response of grain output exceeds this level [3]. As a result, the fertilizer/grain price ratio determines the profitability of fertilizer use. However, it is proved that more accurate estimated coefficients can be obtained when fertilizer/grain price ratio substitutes for separate fertilizer and grain price variables [4]. There are several reasons that this ratio is chosen as an independent variable. Firstly, the prices of both fertilizer and grain have been tightly controlled by the government. Consequently, the large fluctuation of prices has been avoided. It must also be noted that the price of fertilizer has fallen and the price of grain has risen in the last three and a half decades. Secondly, almost all fertilizer has been allocated by government for the urban food procurement [5]. Therefore,

[2]Fertilizer price was deflated by the general agricultural input price index while grain price was deflated by the general wholesale price index in the same year base when 1952 was chosen as base year. Then, the fertilizer/grain price ratio was calculated. All these figures are from China's Statistical Yearbook.

[3]Several soil test results proved this conclusion.

[4]The estimated coefficient for fertilizer price is not statistically significant at the 5 percent significance level if fertilizer price is involved in a regression model with other independent variables such as farm income, technological progresses and grain price.

[5]Op.cit., Stone, p. 462.

farmers have to purchase what they can purchase from state agencies because it is hard to buy fertilizer in the free markets with fluctuating prices based on demand and supply. Thirdly, the rates of response of grain output to incremental applications of fertilizers have remained profitable [6] for farmers throughout this 35-year period.

A short-run model involving one more variable, namely, organic fertilizer, is derived by the use of least-squares method.

$$\widehat{logF_t} = -4.47 - 0.67^{**} \log RA_t + 0.98^{**} \log IN_{t-1} + 0.93^{**} \log T_t + 0.33 \log OF_t \quad (4.2)$$

$R^2 = 0.99$ and $DW = 1.57$

where R^2 is 0.99, indicating that these four variables can explain about 99 percent of the total variation of the fertilizer consumption. The signs of these regression coefficients are exactly as expected. Three coefficients are significant at the 0.99 probability level (b_1, b_2 and b_3). In this equation (4.2), the coefficient for organic fertilizer is 0.33, suggesting that a proportional increase in the use of organic fertlizer will cause an increase in fertilzer consumption. But this coefficient is not statistically significant, predicting that

[6] Stone suggested that the incremental production of grain was consistant with the absorption or application of a combination of nitrogen, phosphorus and potassium. He believed that the rate of yield response to application of fertilizer is approximately constant when the amounts of other inputs to the production process are as large in relation to increased fertilizer supply as in the past. For more detail, see Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China (Washington: International Food Policy Research Institute, 1980).

the effect of the use of organic fertilizer in respect to chemical fertilizer consumption is not significant. Moreover, it can be observed from equation (4.2) that the coefficient for fertilizer/grain price ratio is -0.67, indicating that a 10 percent decrease in price ratio, other things remaining constant, will result in a 6.7 percent increase in fertilizer consumption. Similarly, the effect of farm income in the previous year on the fertilizer purchase in the current year is still significantly high: a 10 percent increase in farm income is predicted to increase fertilizer consumption by 9.8 percent. Also, the coefficient for the time variable is 0.93, suggesting that fertilizer consumption will shift with time. As more information about farm soil nutrient content is gathered, efficient use of different fertilizers is carried out and technical improvements in both fertilizer and crop production are achieved. Consequently, the fertilizer consumption shifts upward with time. Furthermore, the results of this estimate prove all hypotheses and indicate that there is no autocorrelation and heteroscedasticity in this equation.

4.2 Evaluation of the Results of Long-run Models

This section includes several long-run models in the sense that they have a lagged variable for fertilizer consumption over the period 1952-86 [7]. It

[7]It is assumed that long-run model of the demand for fertilizer should be:

$$\log F_t - \log F_{t-1} = B(\log F_t^* - \log F_t)$$

is assumed that farmers would adjust their consumption levels of fertilizer according to the changes in fertilizer/grain price ratio, farm income and time, etc.

Equation (4.3) includes four exogenous variables: the fertilizer/grain price ratio, one year lagged farm income, time and fertilizer consumption in the previous year.

$$\widehat{logF_t} = -2.38 - 0.75^{*} \log RA_t + 1.01^{**} \log IN_{t-1}$$
$$+0.92^{**} \log T_t + 0.03 \log F_{t-1} \qquad (4.3)$$

where B=0.97 b_1= -0.77 b_2=1.04 b_3=0.98 R^2 =0.99 DW=1.65

It can be seen from the results of equation (4.3), all coefficients in this estimate have signs consistent with hypotheses. At the same time, the coefficient for the fertilizer/grain price ratio is statistically significant and the value of it is -0.75, predicting that 10 percent decrease in this ratio will result in a 7.5 percent increase in fertilizer consumption. The estimated elasticity of lagged fertilizer consumption should not be taken too seriously because t-test results indicate that it is not significant at the 5 percent significance level, suggesting the null hypothesis *Ho* should be accepted (this coefficient is essentially equal to zero) and the fertilizer consumption by Chinese farmers in the previous

where F_t is actual consumption level of fertilizer; B is an adjustment coefficient; F_t^* is expected consumption level of fertilizer; F_{t-1} is the actual consumption in the previous year. For more detail, see Martin H. Yeh, "Demand Functions for Fertilizer in Canada," Canadian Journal of Agricultural Economics, Vol. 8, no. 2, p. 55.

year does not significantly affect fertilizer consumpton in the current year. In addition, the elasticity for farm income is 1.01 and is significant at the 1 percent significance level, which indicates that 10 percent increase in farm income will cause a 10.1 percent increase in fertilizer consumption. Moreover, the elasticity for time is 0.92 and is statistically significant, suggesting that the use of fertilizer has increased with time, and that a 10 percent increase in time is predicted to increase fertilizer consumption by 9.2 percent.

The adjustment coefficient B is 0.97 in this equation, suggesting that 97 percent of fertilizer consumption in China is adjusted in a period of time in respect to a change in the fertilizer/grain price ratio, farm income and technological progress. The value of B approaches one, which predicts that farmers adjust their fertilizer consumption level right after the changes in these major variables. On an aggregate basis, farmers undoubtedly need knowledge of changes in the market. A few with proper knowledge and favorable expectations react immediately to purchase as much as they can when they know that fertilizer/grain price ratio will reduce. The process speeds up as other farmers follow. Under this situation, lagged farm income may not be as important as it should be because farmers can borrow money from banks to finance their purchases. On the other hand, the demand for and supply of chemical fertilizer are always unbalanced in China. When the majority of farmers have decided to purchase fertilizer, the remaining farmers must react quickly, otherwise, they can buy nothing. If fertilizer/grain price ratio is unfavorable for farmers, they adjust their current fertilizer consumption immediately because they may no longer benefit from applying fertilizer. Unlike those farmers in developed countries, who can use only a small amount of a certain input in a first period, and slightly more in a second period, Chinese farmers have to respond to the changes in prices of input quickly. Therefore, almost all of fertilizer used is adjusted in the current year. As a result, long-run elastisity for each variable is only 3 percent greater than short-run elasticity. The elasticity for the fertilizer/grain price ratio is -0.77, indicating that 10 percent decrease in the ratio will cause a 7.7 increase in fertilizer consumption. Similarly, a 10 percent change in farm income is predicted to increase fertilizer consumption by 10.4 percent and a 10 percent change in time will result in an increase of fertilizer consumption by 9.8 percent.

The F-test is performed at the 5 percent level of significance. Because the computed F-value (667.6) is much greater than the critical F-ratio, the model is statistically acceptable.

R^2 is 0.99, suggesting that these four independent variables can explain about 99 percent of the total variation of the fertilizer consumption in China.

These variables which seem theoretically and practically reasonable in explaining demand for fertilizer are highly correlated. As a result, it is difficult to isolate their separative effect. For instance, the value of correlation coefficient between lagged fertilizer consumption and time is 0.97, which indicates that the two are highly correlated since fertilizer purchases displayed strong upward trend over most of the period 1952-86. Even though there is correlation between these two variables, it is clear that lagged fertilizer use is not a stronger variable than time because the regression coefficient for time is still significant at the 1 percent significance level and the value of this coefficient does not change significantly compared with the same value in equation (4.1). Moreover, no heteroscedasticity is found by using the Goldfeld test. The Durbin-Watson test result suggests that there is no autocorrelation at the 5 percent significance in this model.

A long-run model involving one more variable, organic fertilizer, is represented by regression equation (4.4). It covers the period 1952-86 for chemical fertilizer in China.

$$\widehat{logF_t} = -4.33 - 0.62^{*} \log RA_t + 0.91^{**} \log IN_{t-1} + 0.86^{**} \log T_t + 0.35 \log OF_t + 0.07 \log F_{t-1} \quad (4.4)$$

B=0.93 b_1= -0.67 b_2=0.98 b_3=0.92 b_4=0.37 and R^2=0.99 DW=1.60

Compared with equation (4.2), the value of R^2 is almost the same. In this distributed lag model, organic fertilizer does not have a statistically significant regression coefficient but has expected sign. With the lagged fertilizer consumption, the coefficients for farm income and time are significant at the 1 percent significance level while coefficient for fertilizer/grain price ratio is significant at the 5 percent significance level. A 10 percent increase in farm income and time is predicted to increase fertilizer consumption by 9.1 and 8.6 percent, respectively, while a 10 percent decrease in the price ratio is predicted to increase fertilizer consumption by 6.2 percent. The adjustment coefficient is 0.93 in equation (4.4). It is assumed in this study that in a long enough time period farmers can adjust their input decisions, and approximately 93 percent of fertilizer consumption must be adjusted in this period because of changes in the fertilizer/grain price ratio, farm income, the use of organic fertilizers and the technical knowledge of farmers. It can be observed that farmers adjust their fertilizer consumption slightly slower when organic fertilizers are available. Similarly, the elasticities for the price ratio is -0.67, indicating that a 10 percent decrease in this item is predicted to increase fertilizer consumption by 6.7. The result also indicates that a 10 percent increase in farm income will increase fertilizer consumption by 9.8 percent. The elasticity of time in response to the fertilizer consumption is 0.86, predicting that a 10 percent increase in time will cause an increase in fertilizer consumption by 8.6 percent. It also can be observed that the elasticity for organic fertilizer is 0.37, suggesting that fertilizer consumption will increase 3.7 percent in response to each 10 percent change in the use of organic fertilizers.

From the estimated result of equation (4.2) and (4.4), it can be seen that organic fertilizer does not have a statistically significant regression coefficient, with or without a lagged fertilizer consumption variable. Equation (4.3), with a lagged fertilizer consumption variable, suggests that farmers adjust their fertilizer consumption based on the fertilizer/grain price ratio in the current year but not based on fertilizer consumption in the pervious year. Furthermore, the lagged farm income evidently is a stronger variable than the fertilizer/grain price ratio and time because it has the highest coefficient value.

Table 4.1 summarizes the estimated results of the short-run and long-run models; at the same time, it includes other specifications of the Chinese demand function for fertilizer over the period 1952-86. The first two models are short-run in the sense that they do not have a lagged variable for fertilizer consumption and the following two equations are long-run models because they include a lagged variable for fertilizer use. The results of these four models have been exhibited in the above two sections.

Four more equations are added to ensure that there is no important variable missing. Two of them (4.5 and 4.6) are short-run models and the others are long-run models. Land (the total sown hectares) is added to the equation (4.5) because it is assumed that fertilizer consumption will increase in response to the increase in the total sown area. Unfortunately, the sign of coefficient for land is unexpected. At the same time, the coefficient for land is not statistically significant at the 5 percent significance level, which indicates that land is not an important variable in the short-run model. it should be noticed that three coefficients for fertilizer/grain price ratio, lagged income and time are still statistically significant as land is added in the equation.

When organic fertilizer is dropped from equation as a variable, the sign of

Table 4.1: Statistical Results and Testing in Demand Functions for Chemical Fertilizer in China, 1952-86

Equations	LogC*	LogRA	LogIN	LogT	LogOF	LogLA	LogF	DW	R^2
4.1	-2.49	-0.77	1.05	0.96				1.63	0.99
	(-6.29)	(-3.1)	(12.2)	(7.3)					
4.2	-4.77	-0.67	0.98	0.93	0.33			1.57	0.99
	(-1.85)	(-2.5)	(8.55)	(6.99)	(0.83)				
4.3	-2.38	-0.75	1.01	0.92			0.03	1.65	0.99
	(-2.39)	(-2.4)	(3.15)	(2.69)			(0.12)		
4.4	-4.33	-0.62	0.91	0.86	0.35		0.07	1.60	0.99
	(-1.72)	(-1.8)	(2.62)	(2.5)	(0.84)		(0.24)		
4.5	-4.11	-0.67	0.98	0.94	0.33	-0.04		1.57	0.99
	(-0.74)	(-2.4)	(8.26)	(6.86)	(0.81)	(-0.07)			
4.6	-3.16	-0.77	1.05	0.95		0.07		1.63	0.99
	(-0.59)	(-3.1)	(12.0)	(7.14)		(0.13)			
4.7	-2.98	-0.75	1.02	0.92		0.06	0.03	1.64	0.99
	(-0.51)	(-2.3)	(3.0)	(2.64)		(0.11)	(0.1)		
4.8	-3.69	-0.61	0.89	0.85	0.36	-0.07	0.08	1.61	0.99
	(-0.63)	(-1.7)	(2.47)	(2.36)	(0.8)	(-0.1)	(0.26)		

Note: LogC* is equal to log of constant and LogLA is equal to log of land. Values in parentheses are t-ratios.

coefficient for land changes to what it should be. But this coefficient is still not statistically significant in equation (4.6). It can be observed that there is no big difference if coefficients in equation (4.6) are compared with corresponding coefficients in equation (4.1) except for a slight change in constant term. This result suggests again that the total sown area in China does not influence the fertilizer purchase decisions made by farmers in the short run because it has largely remained the same throughout the last three and a half decades.

The fertilizer consumption response to land is dealt with the distributed lag models (4.7 and 4.8). The coefficient for land is not statistically significant again even though the sign of it is expected in equation (4.7). Similarly, the sign of coefficient for land is unexpected when organic fertilizer as a variable is in the equation. Furthermore, the coefficient for land is also not statistically significant in equation (4.8).

Theoretically, it is certainly possible that fertilizer consumption may have been affected by the total sown area in China and the application of organic fertilizer in some ways. But it is impossible to isolate the possible impact of these two factors from the impact of the others because the regression coefficients are not statistically significant in both short-run and long-run models.

4.3 Forecast of the Demand for Fertilizer

One of the main goals of applied econometric research is to use the estimated model in order to forecast the value of the dependent variable given the values of the explanatory variables [8]. In this study, forecasting the future demand for fertilizer in China is necessary because the results of forecast influence the nation's investment decisions, the agricultural policy associated with fertilizer price and grain price, etc.

Two approaches are used to forecast the future demand for fertilizer. One is to set up an econometric model, to estimate its parameters from the available data, and then to use this model to predict future quantities of fertilizer demanded. An alternative approach is to use time series data of fertilizer used to forecast its future values.

Forecasting with an econometric model is a complicated process. In this study, a single-equation model is used to predict the future demand for fertilizer. Moreover, it is assumed that the relationship between dependent variable, namely, fertilizer consumption and independent variables, namely, fertilizer/grain price ratio, lagged farm income and time will not change in the forecast period as it was during the sample period, which means that the estimated parameters will be the same throughout the period of 1952-2000.

First of all, the values of the three explanatory variables are estimated according to the assumption that fertilizer/grain price ratio, farm income and

[8] A. Koutsyiannis, Theory of Econometrics (Macmillan Education Ltd, 1986) p. 479.

technological progresses will either decrease or increase as time shifts. For instance, the fertilizer/grain price ratio shifts downward with time. This shift is expected because the government announced that the price of grain would be increased in 1989 for encouraging farmers to sell more grain. Furthermore, the market has played an important role in China since 1978, which means that farmers can get higher grain prices after they submit quotas according to the contract with the state. At the same time, more competition will take place in chemical fertilizer industry through increased production capacity, utilization rates and decreased per unit energy use. Therefore, the price of fertilizer will maintain comparatively stable. When values of these three variables are predicted, and the estimates, all bs, are given, an estimate of the value of the dependent variable can be obtained by substituting for these values in the estimated equation.

The forecasting performance of the econometric model should be judged on the basis of the differences between predictions and realisations. The smaller the differences between predictions and actual quantities of fertilizer used, the better the forecasting performance of the model. Because actual quantities of fertilizer used after 1986 are mostly unknown, the forecasting result is compared with MCI's previous prediction. The model of this study predicted that demand for fertilizer would be 19.73 million tons in 1987, 21.26 million tons in 1988, and 27.08 million tons in 1990. By comparsion, MCI estimated that total demand for fertilizer would be 23.35 million tons in 1990[9]. It is possible that the first two predictions are not significantly different from actual values of fertilizer used. According to average increase rate of fertilizer use from 1952 to 1986, the prediction of future demand for fertilizer in 1990 is overstated.

The difference between the actual and the forecast quantities of fertilizer use may be due to this reason: the relationship between farm income and time is nonlinear, indicating that future farm income should not increase in the same proportion as it was during the period of 1952-86. Therefore, the estimate method of farm income must be adjusted. As a result, a function is applied in the estimation of future farm income as shown:

$$FarmIncome(NI) = AT^{B_1} \tag{4.9}$$

where T is time variable ($T = 1, 2, 3, ...n$) and A is a constant term.

For the purpose of simplicity of the estimation, the function can be written as

$$\log IN = \log A + B_1 \log T \tag{4.10}$$

and future farm income can be estimated when the original data are used in this model:

$$\log IN = 3.54 + 0.66 \log T \tag{4.11}$$

(15.8) (8.26)

[9]Op.cit., MCI, p. 22.

Table 4.2: Future Demand for Fertilizer, 1989-2000

Year	Forecasting (10,000 tons)	Interval (U95-L95)	Year	Forecasting (10,000 tons)	Interval (U95-L95)
1989		1216.4-1942.3	1995	2481.8	1888.9-3260.8
1990	1687.0	1316.6-2163.0	1996	2652.9	2015.9-3491.3
1991	1839.4	1421.3-2380.6	1997	2829.3	2147.2-3728.2
1992	1994.6	1531.9-2597.2	1998	3011.4	2282.8-3972.4
1993	2153.0	1646.9-2815.1	1999	3199.6	2423.1-4224.9
1994	2315.4	1765.9-3035.8	2000	3394.5	2568.3-4486.4

Source: Calculated based on estimated models.

where values in parentheses are t-ratios.

The future demand for fertilizer should be predicted in this way: first, the values of future farm income are estimated based on the equation (4.11). Second, the predicted values of two variables are obtained from other two equations assuming they shift with time. Finally, substituting for the predicted value of these explanatory variables into equation (4.1) yields future fertilizer consumption.

Table 4.2 provides the predicted future demand for fertilizer in the period of 1989-2000. For forecasting performance to be acceptable, future demand for fertilizer should be unbiased forecasts.

The forecasting results of this model are not perfect but acceptable. Firstly, point predictions of future demand for fertilizer before 1991 are less than what they should be because the application of fertilizer already reached 19.3 million ton in 1986. At the same time, confidence interval for point prediction predicts the demand for fertilizer will be 12.6-19.4 million ton in 1989 and 13.2-21.6 million ton in 1990. In view of the fact that the application of fertilizer in forecasting period should exceed the 1986 application level, greater values of confidence interval are more appropriate in 1989 and 1990 periods. Secondly, the forecast value of fertilizer consumption in the year 2000 is unbiased when compared with a former estimate conducted by the Ministry of Chemical Industry (MCI), which estimated that fertilizer consumption would be 33.0 million ton in 2000.

Time series models use only the information from a set of observations on a single variable. These models have provided forecasts that are superior to the corresponding predictions from econometric models[10]. Unfortunately, this is not the case in this analysis. The forecasting performance of any time-series model [11] is not acceptable because the differences between predictions and realisations are far beyond what they should be, even though several important properties such as stationary, white noise, etc. can be obtained.

Several reasons may explain the unacceptable forecasting results in this study:

- time-series models usually need $50 - 100$ observations. In this study, there are only 35 observations;

[10]George G. Judge, el., Introduction to the Theory and Practice of Econometrics (John Wiley and Sons, 1982), p. 667.

[11]These models include autoregressive process (AR), moving average (MA), ARMA and ARIMA.

- the annual increase in rate of fertilizer use in the past 35 years is high, averaging 17.6 percent. Thus the time-series model may not be superior in predicting the future demand for fertilizer in these circumstances.

In this chapter the empirical results for the national demand functions for fertilizer have been analyzed and two approaches have been used to predict the future demand for fertilizer. Next chapter will summarize this analysis and offer some useful suggestions.

Chapter 5

Summary and Conclusion

5.1 Summary of the Study

Although China has a large land base, the country's arable land is quite limited. Only about 10-20 million hectares would be regarded as high quality land for farming compared with other agriculturally powerful countries [1]. At present, there is no large land reclamation project being carried out by the central government. In order to maintain an expected rate of increase in crop output to cope with increased demand from more than 1 billion people for food, employment, raw materials and exports, chemical fertilizers have to be applied in an accelerated rate with related inputs such as organic fertilizer, improved seed and irrigation systems.

Compared with previous studies of China's fertilizer consumption, this study eliminates the uncertainties because of the lack of official information as it uses a more complete statistical data set released by SICAAS recently.

[1]Op.cit., Stone, p. 453.

Moreover, it must be emphasized that no study relating to demand functions for fertilizer has been done in China. Although the methodology used in this study parallels that in Heady and Tweeten's study, the empirical results are totally different.

Overall, this study has examined the relationships between demand for fertilizer in China and several factors such as fertilizer/grain price ratio, farm income, technological progresses, etc. with the single-equation models. At the same time, future demand for fertilizer is predicted. The empirical results obtained in this study can be summarized as follows:

1. Numerous alternative models can be used in specifying demand structure for fertilizer. On a statistical basis, all are acceptable because of their high computed F-values. Among these models, one short-run model appears to be the best which contains three explanatory variables, namely, fertilizer/grain price ratio, lagged farm income and time. The 'a priori' expectations of the signs of the three coefficients are fully satisfied. Moreover, these three coefficients are all statistically significant at the 1 percent significance level. A 10 percent decrease in fertilizer/grain price ratio, the other two variables being held constant, demand for fertilizer will increase by 7.7 percent. Similarly, a 10 percent increase in farm income in the previous year and technological progress will increase fertilizer consumption by 10 and 9.6 percent, respectively. Another noteworthy point is that farm income in the previous year as a variable is a dominant variable in the model because it

has the highest value of coefficient among these three coefficients. It predicts that farmers depend heavily on their income when they make their fertilizer purchase decisions.

2. The results of the long-run model indicate that the fertilizer application in the previous year does not affect fertilizer application in the current year. This phonomenon may be explained since the amount of fertilizer supply is not enough to satisfy the demand in China. Thus, farmers have to purchase what they can purchase from government agencies. On the other hand, most of sown area in China is seriously deficient in nitrogen, phosphate and potash, which calls for more fertilizer application. Moreover, the adjustment coefficient is 0.97 in this long-run model, suggesting that Chinese farmers will adjust their fertilizer consumption in respect to the changes in fertilizer/grain price ratio, farm income and technological progress by about 97 percent in a long enough time period.

3. Organic fertilizer plays a positive role in fertilizer consumption. Organic fertilizer improves the quality of the soil. Unfortunately, the test results indicate that the effect of organic fertilizer on chemical fertilizer use is not statistically significant over the analyzed period. Similarly, the coefficient of land is not statistically significant, suggesting that the change in total sown area in China does not affect demand for fertilizer significantly. This can be explained by the fact that the total sown area in China has largely remained the same in the past 35 years.

4. The predicted future demand for fertilizer in the period of 1989-2000 is acceptable. MCI estimated that demand for fertilizer would be 33.0 million tons in 2000 based on the grain target, soil conditions, the organic fertilizer supply, investment fund, etc. This study estimates that demand for fertilizer will be 33.94 million tons in 2000.

It should be noted that several variables which seem theoretically and practically reasonable in explaining demand for fertilizer are highly correlated. As a result, it is very difficult to isolate their separative effects. Overall, these simple models are quite adequate short-run estimates.

5.2 Implications and Suggestions

The empirical results show that income is the most significant source to affect the demand for fertilizer. In the near future, farm income will continuously increase as government policy encourages farmers to produce more foodgrain, livestock and other products. As farm income increases, demand for vegetables, oils, sugar and livestock products increase sharply in the rural areas. Farmers are no longer satisfied with increased grain consumption, they tend to shift consumption to those products which can provide more calories and more nutrients. Because the production of these products need more fertilizer while agricultural reforms allow farmers to make their own decisions, demand for fertilizer has increased rapidly. As a result, farm income will continuously play an important role on fertilizer use in the future.

The empirical results also support the conclusion that technological progress can increase the marginal yield response to fertilizer application and demand for all fertilizers. At present, a water construction project which diverts water from the Yangtze River to northern China is under construction [2]. About 6.34 million hectares of land will benefit from this project and potential absorption of additional fertilizer in this area will increase. At the same time, high-yield crop varieties such as hybrid rice and corn are continually bred which makes it possible to plant additional crops in some area where normal crops often suffer from heavy losses due to unexpected weather conditions. As the sown areas with new varieties expand, fertilizer consumption will rapidly increase because these high-yielding varieties require nutrients from the soil at an accelerated rate. Furthermore, more and more farmers obtain scientific knowledge of how to use fertilizer more efficiently from short-term training classes and other channels. To gain from efficient use of fertilizer, farmers must choose the application timing and different quantities and different kinds of fertilizer products to grow crops in different seasons, on different types of soil and in different regions. Also new technical developments can reduce nitrogen losses from volatilization and denitrification.

Empirical results indicate that fertilizer/grain price ratio influences demand for fertilizer significantly. It may be a big advantage, within the Chinese system of central planning, that fertilizer price can not widely flactuate

[2] Ibid., p. 483.

when demand for and supply of fertilizer are unbalanced. There is no doubt that the government will step in to adjust fertilizer/grain price ratio when it tends to reach a certain level which reduces farmers' incentives to produce grain. In the near future, the fertilizer/grain price ratio will remain stable. Having learned from past experiences, the government should recognize the role of price because low grain price and tightly controlled grain sales reduced farmers incentives to increase grain production before 1978.

To fully satisfy the demand for fertilizer in the 1990s, the government has to increase its investment in the fertilizer industry. MCI estimated that total investment of 64.4 billion yuan should be collected before the year of 2000 to produce 33.0 million tons of fertilizer [3]. Without doubt, it is almost impossible for China, even under the system of central planning, to collect and allocate this huge amount of capital in the chemical fertilizer industry. Therefore, the government must encourage large public investment in rural areas by using more flexible policies. As a result, investors must benefit from their investment when fertilizer plants in different scales are completed.

The efficiency of fertilizer use must be emphasized. In some regions, there is considerable potential to increase the returns from nitrogen fertilizer by the proper use of phosphate and potash when these two elements become constraint factors. Moreover, agricultural research institutes and universities should tell farmers about their soil conditions based on the soil test results.

[3]Op.cit., MIC, p. 28.

Furthermore, it may be a good point that more fertilizer should de allocated to low and medium quality land to gain increasing returns. Also more efforts must be made to reduce nitrogen losses from volatilization and poor packaging.

Although the supply of organic fertilizer is constrained by the natural growth limits of the generating sources, there is still room to increase organic fertilizer application in the future, e.g., supporting alternative rural energy schemes by building more biogas digesters in southern China and distributing low quality coal in northern China in order to allow more crop residues to be used as organic fertilizer. The government should encourage farmers to collect more organic fertilizer to improve their land. The recent trend of decreasing use of organic fertilizer should be discouraged because organic fertilizer still makes up the bulk of total nutrient supply for crops in China.

Appendix A

Chemical Fertilizer Industry since 1949

In 1840, Mr. John Lawes began his experiments with new method to make chemical fertilizer at the Rothamsted Experiment Station in England. He tested a new process for making superphosphate with mineral phosphates instead of animal bones. Before 1840, animal bones were treated with sulfuric acid to produce phosphate. Two years later, he patented the new process. In 1845, Justus von Liebig, a German, first introduced the value of potash salts to the German public.

Before the Communist take-over in 1949, there were only two nitrogen fertilizer plants in China. One was built by Japanese in Dalian and the other by the Yung Li Company, a Chinese owned enterprise, in Nanjing (Kuo, 1976). Ammonium sulfate was the only product for both plants and the highest annual output was 227,000 tons in standard weight. In 1949, the annual output of chemical fertilizer was only 6,000 tons in nutrient weight

(SICAAS, 1986).

After the People's Republic of China was established, the new government paid considerable attention to the chemical fertilizer industry. During the periods of the First Five-Year Plan (1953-1957) and the Second Five-Year Plan (1958-1962), 2.4 billion yuan was invested in expanding two existing chemical fertilizer plants, constructing several medium-scale nitrogen fertilizer plants, each with an annual production capacity of 50,000 to 75,000 tons, and three large-scale nitrogen fertilizer plants in Kirin, Taiyuan and Lanchou (Kuo, 1976). During the period 1963-1965, more than 1 billion yuan was invested to continue these projects. In 1953 the output of nitrogen fertilizer was 50,000 tons, which broke the record of the highest output created in 1941. The output of nitrogen fertilizer reached 1.037 million tons in 1965 [1], 20 times more than the output in 1953 (SSB, 1987). By the end of 1969, more than 21 large-scale chemical fertilizer plants had been built (Kuo, 1976). One year later, the output of nitrogen fertilizer was 1.523 million tons. During the period 1953-1970, both production and application of chemical fertilizers increased rapidly, but the demand for food grew even faster. As the Soviet Union entered international market and the oil crisis expanded, the prices of both grain and chemical fertilizer were rising. In 1972 the government decided to import 13 large-scale complexes, each with an annual production

[1]According to Dr. Kuo, nitrogen fertilizers which were produced in that period included ammonium nitrate, ammouium sulfate, ammonium chloride, calcium cyanamide, urea, ammonia water and ammonium bicarbonate.

capacity of 300,000 tons synthetic ammonia, which could be converted to urea, or 500,000 tons urea (SICAAS, 1986). The total investment from 1971 to 1980 was 14.37 billion yuan, the highest capital investment to chemical fertilizer industry in a 10-year period since 1949. By the end of 1979, all these complexes had been installed and began to produce nitrogen fertilizers. Assisted by continued rapid development of small scale plants, the output of nitrogen fertilizers increased from 2.44 million tons in 1972 to 9.99 million tons in 1980 and 11.59 million tons in 1986 [2], which output puts China in the position of being the second largest nitrogen fertilizer producer in the world [3].

The Wu Ching Chemical Fretilizer Plant was the first large nitrogen fertilizer plant designed and constructed by Chinese engineers and workers. The first-stage installation of this plant at Shanghai was completed in September, 1963 (Kuo, 1976). Many heavy machinery and electrical equipment factories all over the country were involved in this project and supplied full sets of equipment. In 1965 a new workshop at Wu Ching Chemical Fertilizer Plant went into trial operation. By the end of 1970s, the Wu Ching Chemical Fertilizer Plant had been completed with an annual production capacity of 300,000 tons synthetic ammonia. The tremendous success of this project indicated that China was able to design and construct a large-scale

[2]SSB, China's Statistical Yearbook 1984, p. 175; China's Statistical Yearbook 1987, p. 146.

[3]SICAAS, op.cit., p. 2.

Table A.1: Investment in Chemical Fertilizer Industry, 1953-1985

Period	Total investment in China (billion yuan)	Investment in chemical fertilizer industry (billion yuan)	Share of total capital investment (percentage)
1953-1957	54.99	0.455	0.82
1958-1962	118.66	1.936	1.63
1963-1965*	33.50	1.005	3.00
1966-1970	91.47	2.762	3.02
1971-1975	168.04	6.964	4.14
1976-1980	224.28	7.402	3.30
1981-1985	339.71	3.194	0.94

Note: * figures are estimated according to the growth rate released by different sources. Source: MCI, "The Aim and Policy of Development in Chinese Chemical Fertilizer Industry," Nong cun jing ji wen gao(Rural Economic Draft), Dec, 1987, p. 25.

chemical fertilizer plant and manufacture full sets of equipment such as large high-pressure compressors, large ammonia converters, high-pressure seamless steel pipes, etc. During the 1960s, several other large scale chemical fertilizer plants, using equipment designed, manufactured and installated by Chinese technicians, were under construction or were put into operation (Kuo, 1976).

During the Great Leap Forward campaign period (1958-1960), many small-scale chemical fertilizer plants were built in rural areas. The central government encouraged the development of these so called "native method fertilizer plants" and hoped that these plants could rapidly increase fertilizer output to make up for the lack of organic fertilizer supply. Because almost all chemical fertilizers were allocated by the central and provincial governments, and chemical fertilizers were provided in exchange for procurement, many communes could not obtain a proportion share of chemical fertilizers, because either they did not have surplus grain for sale or they were located in remote areas. As a result, these communes had strong initiatives to build thier own chemical fertilizer plants. On the other hand, communes which could get a chemical fertilizer supply were also willing to invest in fertilizer plants because they did not obtain enough chemical fertilizer as they needed. Thus many small-scale fertilizer plants were built in unfavourable conditions where well-trained workers and suitable equipment were in short supply and where capital funds for investment were also limited because these plants were financed locally. Consequently, most of the fertilizers produced by these plants were low grade, only one-tenth to one-twentieth as effective as those produced in modern chemical fertilizer plants (Kuo, 1976).

The method of producing chemical fertilizers in some of these small-scale plants was primitive. At the beginning, nitrate rocks, bones, seaweed and askes from grasses and trees were transformed into powder and liquids, then mixed, boiled and drained. A fertilizer produced in this way contained a certain amount of nitrogen, phosphate and potash and sometimes was either too acidic or too alkaline for the local soil [4].

To increase the efficiency of these small-scale fertilizer plants, many engi-

[4]Kuo, op.cit., p. 149.

neers, experts and working teams were sent to change the production methods in these plants. The Dairen Chemical Company even built a synthetic ammonia plant with an annual output of 800 tons standard fertilizer as a model to show how a small fertilizer plant could be improved at a low cost. In 1962 Hou Tepang, an American-trained engineer and staff at the Nanjing Chemical Fertilizer Company, developed a new process of producing ammonium bicarbonate containing 17.5 percent nitrogen. As a result, the development of small chemical fertilizer plants began to accelerate. In 1965 there were about 800 small fertilizer plants [5]. By 1966, 18 percent of China's nitrogen fertilizer was from these small plants producing synthetic ammonia, which was converted to ammonium bicarbonate (Stone,1986). The proportion of total domestic nitrogen fertilizer output contributed by small plants was 43 percent in 1969, 53 percent in 1972 and 60 percent in 1974 (Kuo,1976). From 1969 to 1978, 1,225 small-scale chemical fertilizer plants came into operation and their production capacity ranged from 3,000 to 5,000 tons a year (SICAAS). The number of small plants had risen to 2,000 by 1974, after which many small plants were closed down or merged with others because of low plant efficiency (OECD,1985). By 1978, there were 1,533 such plants producing 70 percent of China's nitrogen fertilizers (Stone, 1986). Recently, the number of fertilizer plants is more than 1,800 (except those run by collectives), among which there are about 1,100 small-scale nitrogen fertilizer plants and 600

[5] OECD, op.cit., p. 53.

small-scale phosphate fertilizer plants [6]. These plants produce about 62.8 percent of the nation's chemical fertilizers [7].

Compared with those of large or medium-scale fertilizer plants, the investment costs per ton nitrogen fertilizer produced at the small plants were lower. These costs were 1,400, 1,200 and 600 yuan, respectively [8]. But the production cost at the small plant was found to be high, 400 yuan per ton, while it was 180-200 yuan per ton at the large plant (Kuo,1976). Similarly, the requirement of materials to produce one ton of nitrogen fertilizer at the small plant was 2-3 times more than that at the medium-scale plant (Stone,1986). Thus the Ministry of the Chemical Industry began to amalgamate small fertilizer plants that were making inefficient use of machinery, energy transport, etc., and to control the further construction of small-scale fertilizer plants in the early 1980s (OECD,1985).

Overall, the small plant exhibits some merits. First, it brings quicker results. In a 3-4 year period, one small plant can be built and fully operated while more than 7 years are needed to set up a large plant. Second, the small plant uses local resources which may not fit either quality or quantity needs of the conventional plant. Third, it is easy to distribute fertilizers to users without any delay because most of these plants are located in the rural areas. Fourth, it is easier for workers to operate the small plant.

[6] The Ministry of Chemical Industry (MCI), "The Aim and Policy of Development in Chinese Chemical Industry," Nong cun jing ji wen gao, Dec, 1987, p. 26.

[7] Ibid.

[8] Ibid.

During the 1950s, an estimated 40-50 percent of China's farmland was deficient in phosphates (Stone,1986). In 1984 the Chinese Academy of Agricultural Science released its second field test results, estimating that 73 percent of arable land was deficient in phosphates and 40 percent was seriously deficient [9]. Recently, nearly 80 percent of arable land north of the Yangtze river is deficient in phosphates [10]. Deficiency for phosphates limited the crop response to nitrogen and became a constraint factor.

Production of phosphate fertilizers began in 1953. Several small-scale phosphate fertilizer plants were built and only calcium superphosphate was produced. Compared with the effect of small nitrogen plants, small phosphate fertilizer plants were far more important in the development of phosphate production. Because of the longer period of construction and the absence of high grade ore in developed regions, the large scale plants developed slowly. In 1956 the output was 14,000 tons in nutrient weight[11]. During the First Five-Year Plan period, two large scale phosphate fertilizer plants were constructed in Nanjing and Taiyuan. In 1962 Chanchiang Chemical Industry Plant, with an annual production capacity of 100,000 tons of phosphate fertilizers was built with state financing. Two years later, China had nearly 100 phosphate fertilizer plants with an aggregate annual production capacity of

[9]SICAAS, op.cit., p. 13. It is believed that readily available phosphrous content on the different types of soil should exceed 10 ppm. If the available phosphrous content is less than 5 ppm, the land is seriously deficient in phosphates. When the content is 5-10 ppm, the land is considered to be deficient in phosphates.

[10]SICAAS, op.cit., p. 13.

[11]Ibid., p. 2.

2 million tons in different areas, and most of these plants produced calcium superphosphate and calcium magnesium phosphate (Kuo,1976). In 1983 the output of phosphate fertilizers was 2.66 million tons in nutrient weight, which put China into the third position in the world, following the United States and the Soviet Union (SICAAS,1986).

During the 1950s, Chinese farmers were slowly becoming familar with phosphate fertilizers. First of all, detailed field tests on most of farm areas and techniques of application had not been done. Therefore, farmers did not obtain significant effectiveness when they used phosphate fertilizers in the field where the phosphate content is high. According to Bruce Stone, only about 15 percent of the phosphate nutrient can be readily absorbed by plant root systems, and other 85 percent nutrient is either built up in the soil, slowly released over time in years, or eroded away by water or wind. Thus, imporper use of phosphate fertilizer in the field without any information about soil resulted in low response. At the same time, the absence of adequate equipment and skilled workers caused poor quality fertilizer products. If imporperly applied, these low quality products can even damage crops. By the end of 1960, large stocks of phosphate fertilizer began to build up, even with enormous subsidies. Therefore, phosphate production declined sharply in both 1961 and 1962 [12].

[12] Owen L. Pawson, Communist China's Agriculture, its Development and Future Potential (New York: Praeger Publishers, 1970), p. 123.

In 1962, the field test result of national network for experimentation with chemical fertilizer was released by the Chinese Academy of Agricultural Science. It indicated that the cultivated land south of the Yangtze River was deficient in phosphate. To improve soil fertility and increase crop output, production and application of phosphate fertilizers had been encouraged and technique of effective use of phosphate fertilizers had been shown. Many difficulties confronting the industry in these south provinces had been overcome. Accoding to SICAAS, the sale of phosphate fertilizers in 13 southern provinces accounted for 80 percent of the nation's total in the period of 1956-1976. The major efforts were:

- large-scale programs of soil testing and crop experiments were carried out by provincial agricultural research institutes and universities;
- large numbers of technicians and workers were trained;
- many phosphate fertilizer plants were built in those areas of Yunnan and other provinces where high grade ore is available;
- adequate equipment with the technology of the 1950s was provided;
- reasonable prices were offered to farmers with enormous subsidies.

As a result, farmers began to benefit from the use of phosphate fertilizers and the sale of them increased rapidly. Sometimes the supply of these fertilizers could not satisfy the demand in these southern provinces. In 1962 the use of phosphate fertilizer in China was 125,000 tons and the number even reached 854,000 tons in 1966 and 1.16 million tons in 1971 [13]. The dramatic increase in the sale of phosphate fertilizers enabled the phosphate industry to expand its production capacity. Production climbed from 126,000 tons in 1962 to 1.08 million tons in 1971 and 2.66 million tons in 1983[14].

Among all provinces, Guangdon and Guangxi have made the most significant progress in the production and use of phosphate fertilizers; about 80 percent of the cultivated farmland was applied with phosphate fertilizers in Guangdon in 1963. Since then, many phosphate fertilizer plants have been constructed. Consequently, the readily available phosphate content in the soil is high in these two provinces.

There are several serious problems in China's phosphate fertilizer industry. First, the high grade phosphate ore is lacking in the ralatively developed provinces but is available in remote areas of Yunnan and Guizhou, two undeveloped provinces in the southwest China. Therefore, the further development of phosphate production is constrained by ore source supply. Second, most of the Chinese phosphate ore contains low phosphate and high impurities, which causes high production costs. Third, most phosphate fertilizers consist of only 12 percent phosphate, which is lower than the 18 percent of standard weight. Thus the quality of phosphate fertilizer has to be improved continuously. The proportion of higher analysis products such

[13] Op.cit., SICAAS, p. 7.
[14] Ibid.

as triple superphosphate, diammonium phosphate and compound fertilizers must be increased in phosphate fertilizer production. Finally, the supply of electricity, construction funds and materials in China is unstable. When shortages in these items develop, the phosphate fertilizer sector has been an easy target for temporary cutbacks [15].

The Chinese Academy of Agricultural Science estimated that 22.8 percent of arable land, mostly located south of the Yangtze River, was deficient in potash [16]. In addition, 1983 field test results indicated that 13.4 percent of arable land was deficient in boron and 6.7 percent was deficient in zinc. Studies also revealed that deficiency for trace elements such as manganse, copper and molybdenum have begun to appear in some areas [17].

The development of potash production has been insignificant since 1949 because of the limitation of resources. In 1983 the output of potash fertilizers was 29,000 tons and the application reached 584,000 tons [18]. However, most of potash fertilizers must be imported. Trace elements can be produced in China and the application averages 50,000 tons [19].

For years, the government has attempted to maximize total grain output by using chemical fertilizer as an instrument on agricultural production and procurement. Disproportionately high chemical fertilizers, particularly nitro-

[15] Op.cit., Stone, p. 475.

[16] Soil Institute, the Chinese Academy of Agricultural Science, believed that less than 70 ppm effective potash remained in the soil indicates deficiency for potash.

[17] Op.cit., SICAAS, p. 15.

[18] Ibid.

[19] Ibid., p. 7.

gen, has been allocated to high-yield regions where there are many advantages such as better irrigation facilities, high soil fertilities and adequate weather conditions. In addition, many commercial grain bases and state farms obtain more chemical fertilizers. Consequently, northern China receives less chemical fertilizer allocation. Moreover, the favored crops for fertilizer distribution are rice and wheat. Among cash crops, cotton is the top priority crop for chemical fertilizer distribution. Tuber crops, as well as soybeans and peanuts, receive little. As a result, diminishing returns in some of these "high and stable yield" regions and for some crops have emerged [20]. However, these priorities have come to conflict with maximization of benefit because more fertilizer distribution on low-yield farmland may produce increasing returns.

The waste in distribution and inefficient use in production have caused serious problems. First, poor packing, inefficient inland river transport system and inadequate storage conditions have resulted in heavy damages and losses of chemical fertilizers. According to an estimate, 20 percent of bags are damaged annually, causing a loss of 1.2 million tons of chemical fertilizers [21]. In addition, many warehouses are inadequate for storing chemical fertilizers: the floors are damp and the temterature is high in summer. If there is no measure to separate the chemical fertilizers from the damp floors and high temperature, the fertilizer is moistened and decomposed. Second, many

[20] According to second field test result, the effect of fertilizer per unit applied had been reduced.

[21] Op.cit., Hsu, p. 58.

farmers simply spread the ammonium bicarbonate over the field and expose it in the air. Under high temperature, readily available nitrogen rapidly decomposes and evaporates (Kuo,1976).

Unfortunately, detailed imformation on the soil conditions of local farming areas has not been gathered. Unlike the United States, farmers could not bring their soil samples to local universities or analytic stations and receive a detailed analysis of the soil nutrient content in China because county level laboratories began only in 1980 (Stone,1986). Qualified technicians and available equipment are also seriously lacking. For instance, a county may not have a university graduate whose major is soil science. As a result, many farmers do not know the exact conditions of their land and have not used the appropriate fertilizers even though the second soil test was completed in 1983 [22].

Sometimes the appropriate fertilizers may not be available even though detailed soil information is received. As mentioned above, disproportionately high fertilizer allocations are concentrated on "high and stable yield areas", not based on what these areas need but based on what is available. Those of low and medium yield land may not receive enough phosphate fertilizers when

[22] Although a national network for soil test was set up in 1958-1960 and useful soil test has been conducted at several provincial agricultural academies, a county level laboratory system does not yet exist in China. The nutrient content in the soil changes over time because many factors affect the balance of nutrients such as the types of soil, weather conditions, fertilizer application levels, etc. It will help to guide the fertilizer application on the different types of soil with quick and accurate results by testing soil samples in different regions every 3-5 years.

the soil test results indicate the land needs to supply phosphate nutrients. Moreover, the production of nitrogen, phosphate and potash is unbalanced. In 1986, the output ratio of these three fertilizers was 1 : 0.2 : 0.002 in China while in industrialised countries it is about 1 : 0.7 : 0.6 [23].

[23] Op.cit., SICAAS, p. 29.

Appendix B

Tables

Table B.1: Estimated Supply of Organic Fertilizers in China, 1952-78

Year	Night soil	Hog manu*	Sheep manu	Other manu	Green manu	Oil cakes	Plant residues	River mud	Total manu
1952	165.3	50.6	19.9	166.2	13.1	34.4	292.1	11.8	753.3
1953	172.4	55.6	23.9	180.9	16.9	35.8	276.5	12.7	774.7
1954	180.4	60.5	27.7	196.7	21.7	32.8	292.1	13.6	825.4
1955	187.6	53.7	29.4	208.7	25.5	32.9	299.8	14.6	852.2
1956	199.0	53.6	33.4	218.8	36.6	37.5	304.8	16.0	899.7
1957	208.9	95.4	36.9	214.8	47.2	36.9	291.2	16.0	947.1
1958	242.0	97.0	38.4	214.0	54.4	42.7	289.5	17.2	995.0
1959	227.1	80.1	42.5	208.1	48.3	34.6	279.6	16.3	936.6
1960	211.0	55.6	43.7	197.6	39.3	26.0	263.8	16.6	854.3
1961	213.8	51.1	48.0	188.1	40.8	22.6	249.9	16.6	830.8
1962	221.5	66.5	51.3	187.0	43.6	24.3	257.4	16.3	867.8
1963	241.6	90.9	55.3	207.6	54.2	25.5	265.3	16.3	956.5
1964	258.0	110.9	56.9	231.8	69.6	23.6	285.6	16.6	1052.9
1965	282.2	129.3	61.7	259.9	83.9	23.7	308.2	16.8	1165.8
1966	284.4	147.2	60.2	263.0	91.7	25.3	314.3	16.6	1202.5
1967	297.1	142.2	61.8	264.3	100.2	26.9	317.4	16.3	1226.2
1968	305.7	133.6	61.8	270.2	111.5	29.2	324.4	16.3	1252.7
1969	319.4	131.3	61.1	281.3	126.2	32.2	331.8	16.6	1299.8
1970	328.2	156.9	64.1	287.8	140.4	35.0	339.3	16.6	1368.1
1971	335.8	190.5	65.4	290.8	148.5	33.4	342.9	16.6	1423.8
1972	342.9	200.7	65.1	292.1	157.0	31.8	344.3	16.6	1450.4
1973	350.7	196.3	68.5	296.5	166.0	30.3	349.4	16.6	1474.5
1974	358.2	198.5	70.1	297.8	175.6	28.9	350.7	16.6	1496.2
1975	364.4	214.0	71.2	295.7	185.7	27.5	348.3	16.6	1523.4
1976	369.3	281.6	68.9	290.1	185.0	25.2	341.5	16.6	1578.2
1977	367.3	218.3	69.1	281.4	181.1	27.3	331.2	16.3	1491.8
1978	363.9	221.5	71.6	277.3	177.3	27.8	326.1	16.0	1481.5

Note: Table will continue on next page.

Table B.2: Estimated Supply of Organic Fertilizers in China, 1979-86

Year	Night soil	Hog manu*	Sheep manu	Other manu	Green manu	Oil cakes	Plant residues	River mud	Total manu
1979	372.1	239.1	78.4	284.3	171.3	27.8	334.2	16.3	1523.6
1980	373.7	228.4	80.2	285.9	155.4	29.6	336.6	16.3	1506.2
1981	377.8	219.7	80.4	292.4	158.0	34.8	345.0	16.3	1524.3
1982	397.9	239.1	82.7	283.7	158.0	34.8	345.0	16.3	1557.4
1983	387.9	237.3	75.9	290.3	158.0	34.8	345.0	16.3	1545.6
1984	348.8	243.9	72.0	304.0	158.0	34.8	345.0	16.3	1522.8
1985	328.1	263.5	70.9	319.3	158.0	34.8	345.0	16.3	1535.8
1986	306.7	268.0	75.6	333.7	158.0	34.8	345.0	16.3	1538.2

Note: Formula $NF = Q \times U \times (n+p+k) \times An/Ac$ is used in this estimation. Kueh estimated the supply of organic fertilizer in the 1952-1982 period and author estimated the remaining while these items such as green manure, oil cakes and river mud were assumed to be constant because of scarcity of information. Manu is equal to "manure".
Source: Y.Y. Kueh, "Fertilizer supplies and foodgrain production in China, 1952-82," Food Policy, Vol. 9, no. 3 (August), p. 224.

Table B.3: Grain Output in China, 1949-86

Year	Grain output (milliontons)	Year	Grain output (milliontons)
1949	113.18	1968	209.06
1950	132.13	1969	210.97
1951	143.69	1970	239.96
1952	163.92	1971	250.14
1953	166.38	1972	240.48
1954	169.52	1973	264.94
1955	183.94	1974	275.27
1956	192.75	1975	284.52
1957	195.05	1976	286.31
1958	200.00	1977	282.73
1959	170.00	1978	304.77
1960	143.50	1979	332.12
1961	147.50	1980	320.56
1962	160.00	1981	325.02
1963	170.00	1982	354.50
1964	187.50	1983	387.28
1965	194.53	1984	407.31
1966	214.00	1985	379.11
1967	217.82	1986	391.51

Source: China's Statistical Yearbook, 1984-87.

Table B.4: Sown Area and Cultivated Area in China, 1952-86

Year	Sown area	Cultivated area	Year	Sown area	Cultivated area
1952	211884	161879	1970	215231	151650
1953	216053	162794	1971	218526	151095
1954	221888	164033	1972	221878	150552
1955	226622	165236	1973	222821	150000
1956	238759	167738	1974	222953	149783
1957	235866	167745	1975	224318	149565
1958	227992	161681	1976	224584	149250
1959	213607	160950	1977	224000	148950
1960	225863	160800	1978	225156	148950
1961	214821	160650	1979	222715	149400
1962	210343	159333	1980	219569	148950
1963	210327	158028	1981	217736	147600
1964	215297	156734	1982	217132	147600
1965	214936	155385	1983	215990	147600
1966	220243	157950	1984	216332	147600
1967	217414	160500	1985	215439	147600
1968	209741	157550	1986	216306	145815
1969	211416	154655			

Note: The units are 10 thousand mu.
Source: China's Statistical Yearbook, 1984-87.

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