GRAIN PRODUCTION IN CHINA
Productivity Changes and Provincial Disparities, 1978-1990

By

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To my family and teachers

Contents

Chapter 6 Estimation of Grain Production Functions and Analysis of the Parameters 124

Chapter 7 Changes in Total Factor Productivity and Sources of Yield Growth 158

List of Tables

List of Figures

List of Maps

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Research Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Abstract

This study investigates changes in the total factor productivity of grain production and their contribution to the growth of grain output between 1978 and 1990. It focuses on examining the factors responsible for changes in total factor productivity. Particular attention is devoted to exploring the causes of the disparities among provinces and respective grain crops. Relative provincial production efficiency in terms of resource utilisation is also examined.

The foundation underlying the whole study is the view that the growth of grain output is the result of increasing inputs and/or of improving total factor productivity. The analysis found that during the period studied, the rapid improvement of total factor productivity was an important source of the growth of grain output. However, this effect was only significant during the early years of the 1980s. After 1985, the growth of grain output was mainly the result of increasing inputs, while total factor productivity stagnated.

The study argues that the rapid improvement in total factor productivity during the early 1980s stemmed from the one-time gains of the implementation of the Household Responsibility System. This effect reached its limit by the mid 1980s. Further improvement of total factor productivity, therefore, has to rely on innovation and the application of new technology to extend the production frontier as well as on policies providing incentives for grain production. However, during the whole period studied, government polices with respect to agricultural investment, agricultural research, promotion of technology and marketing reforms were generally unfavourable to the improvement of total factor productivity of grain production. The increase in the grain price during the early 1980s had a positive effect on the improvement of total factor productivity. After 1985, the generally low relative prices of grain have also been responsible for the stagnation of total factor productivity during the second half of the 1980s. The effect of low relative prices, however, has been intensified by the small scale of household arable land, which constrains the improvement of labour productivity and therefore household incomes.

The variations in the growth of total factor productivity among provinces were significant, and were found to be closely related to the uneven development of the rural economy in different areas. The disparities in the growth pattern of total factor productivity among grain crops were associated with the demand for different grain crops and the level of central control over production.

The study found a close relationship between natural conditions and the level of production efficiency in different provinces for respective grain crops. Specialisation of grain production in the areas where natural conditions are favourable for a particular grain crop, therefore, is conducive to raising the efficiency of national resource utilisation. It is argued, however, that due to the central government's administrative intervention, provincial grain production is sometimes unable to pursue the path of the most efficient use of available resources. Entirely removing the central control over grain production is considered to be necessary for further improving total factor productivity and for a more efficient use of national resources.

Abbreviations

1 Sources cited in the thesis

ECCAY:	Editorial Committee of the Chinese Agricultural Yearbook
ECCREY:	Editorial Committee of the Chinese Rural Enterprises Yearbook
ERS:	Economic Research Service
QNCSZH:	National Survey of Costs and Returns of Agricultural Production
SPB:	The State Price Bureau
SSB:	The State Statistical Bureau
USDA:	United States, Department of Agriculture
ZNN:	Chinese Agricultural Yearbook
ZNTN:	Chinese Rural Statistical Yearbook
ZNTZ:	Statistics of Chinese Agriculture
ZTN:	Chinese Statistical Yearbook
ZWN:	Chinese Price Yearbook
ZWTN:	Chinese Price Statistical Yearbook
ZXQN:	Chinese Rural Enterprises Yearbook

2 Names and Identity Numbers of Provinces

1. BJ:	Beijing
2. TJ:	Tianjin
3. HB:	Hebei
4. SX:	Shanxi
5. NMG:	Neimenggu
6. LN:	Liaoning
7. JL:	Jilin
8. HLJ:	Heilongjiang
9. SH:	Shanghai
10. JS:	Jiangsu
11. ZJ:	Zhejiang
12. AH:	Anhui
13. FJ:	Fujian
14. JX:	Jiangxi
15. SD:	Shandong
16. HN:	Henan
17. HUB:	Hubei
18. HUN:	Hunan
19. GD:	Guangdong
20. GX:	Guangxi
21. SC:	Sichuan
22. GZ:	Guizhou
23. YN:	Yunnan
24. SAX:	Shaanxi
25. GS:	Gansu
26. QH:	Qinghai
27. NX:	Ningxia
28. XJ:	Xinjiang

3 Others

HRS:	Household Responsibility System
mha:	million hectare
mmt:	million tonnes
mmu:	million mu
TFPI:	Total factor productivity index

Chapter 1

Introduction

1.1 The Background of The Study

Grain production is the most important component of China's agriculture. Producing sufficient grain to meet an ever-increasing demand is always a high priority for the Chinese government. Since 1978, with the beginning of the rural reforms, China's agriculture has undergone significant changes. One of the most important results has been the rapid increase in total grain output. Between 1978 and 1990, grain output increased by 46.4 percent, and the annual growth rate was 3.23 percent compared to an average of 2.5 percent between 1952 and 1978 (SSB, *ZTN*, 1983 and 1991). Thanks to this rapid increase in grain output, average grain production per capita increased from 318.7 kg in 1978 to 393.1 kg in 1990, despite a population increase of 180.74 million during the same period (SSB, *ZTN*, 1991). This represents a remarkable achievement, considering that China has to feed 22 percent of the world's total population with only 7 percent of the world's total arable land.[1]

Given that there has been a rapid growth in grain output, one needs to ask, what have been the factors contributing to this growth? An increase in

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[1] The official figure for total arable land is 1435.1 million mu (1 mu = 1/15 hectare) (SSB , *ZTN*, 1991). However, it is widely believed that the actual total for arable land is larger than the figure in Chinese official statistics. The extent to which this underreported figure can affect the analysis of this study will be discussed in Chapter 3.

grain output can occur as a result of increased inputs, including land, labour and capital, as well as by improving the productivity of inputs (or total factor productivity).[2] The latter involves two aspects: improvements in technology (or technological progress) and more efficient production management under the given technology (or technical efficiency).[3] Compared with increasing the quantity of inputs, however, improving the productivity of inputs is more significant for grain production, due to the extra output that can be obtained, given the level of inputs. This means an improvement in production efficiency in terms of resource utilisation. The aim of this study is to explore the sources of the growth and to investigate the changes in the productivity of grain production during the reform period in China.

In China, research into the productivity of inputs has not been given much attention until quite recently. One of the reasons was that both agricultural production and agricultural studies were influenced by the overall political imperatives, which emphasised growth of total output rather than improvement in productivity. Since the founding of the People's Republic, feeding the huge population has always assumed high priority for the Chinese leadership. Although great efforts were made to increase grain output, for many years, grain supply was only barely sufficient. In the 1960s, China changed from being a net grain exporter to being a net importer. This situation further strengthened the resolve of the government to increase grain output, while paying little attention to the costs of production and the levels of productivity. This emphasis continued through the 1960s and into the late 1970s.

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[2] The definition of productivity will be discussed in Chapter 2.

[3] According to Thomas, where there are increasing returns to scale, increasing scale is also a source of output growth (Thomas, 1993, p.296).

Beginning in the 1980s, however, concern with productivity has become one of the major issues in studies of Chinese agricultural production. Four factors have contributed to this concern.

First, the relaxation of the state controls over farmers' production decisions, one of the major policies implemented since the reforms, has stimulated farmers' awareness of the need to minimise production costs and to maximise profits. Increasing productivity is essential for them to achieve these goals, given the level of prices. The significant improvement of farmers' subsistence food consumption has further reinforced this awareness because farmers can now give consideration to more than merely increasing output to ensure their own food security.

Second, the reforms reflect the ideology of policy makers, which has been changing from emphasising political struggle to emphasising economic development. Economic efficiency subsequently has become an increasingly important concern for policy makers and this, in turn, has led to a desire to improve productivity.

The third factor is that the relaxation of the international political environment and China's growing involvement in international trade has reduced the strategic concerns about grain self-sufficiency. This leaves room for considering the efficiency of grain production, although maximising grain output and achieving grain self-sufficiency are still seen as strongly desirable.

The fourth and last factor is perhaps the most important one. Following a rapid growth of grain output in the early years of the reforms, the growth of output slowed down in the later years of the 1980s. In contrast, grain production costs have escalated rapidly. For example, in 1984, the unit material cost of rice production was 33.6 yuan/mu, whereas by 1990 it had risen to 50.81 yuan/mu (SPB, *QNCSZH*, 1984, 1991), an increase of 51.5 percent.[4] During the same period, however, the rice yield only increased from 358 kg/mu to 382 kg/mu (SSB, 1991, p.353), a rise of 6.7 percent. A similar situation was also evident in other grain crops, including wheat, corn and soybean. The unit production costs all increased substantially in the late 1980s. The rapid increase in grain production costs has intensified the general concern about productivity and efficiency.

Although studies of the productivity of Chinese agriculture have become more common since the late 1980s, systematic work on this issue is still a frontier area. This is not only because such concern has just began, but also because studies have been constrained by data availability. Historical data for inputs and production costs in grain production are generally inadequate and are almost absent for the period of the 1960s and the early 1970s, due to the turmoil of the Cultural Revolution. The accuracy of the available data is also poor. All these problems make the historical analysis of productivity extremely difficult. Partly for this reason, most of the previous studies of Chinese agricultural productivity have focused on the situation since 1978, when more data have been recorded at both the national and the local level.

Another important reason for concentrating on the period of the reforms since 1978 is that it has been the most important era in China's agricultural production. During this period, a series of new policies has been implemented in the rural areas which has brought about fundamental changes and rapid development of the rural economy. Along with such

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4 The figures have been deflated to 1978 constant prices by using the price index of producer goods provided by the State Statistical Bureau (SSB, *ZTN*, 1991, p.243).

changes, agricultural production has increased remarkably. Modern inputs have been widely used to substitute for traditional inputs. All this has happened with important changes taking place in the structure of agricultural production as a whole. At this time, systematically examining the sources of growth and the efficiency of agricultural production is not only significant but also necessary for a better understanding of the achievements as well as the remaining problems of agricultural production during the reform period.

This study focuses on grain production, the most important sector of agriculture. It analyses sources of output growth and the factors responsible for changes in productivity between 1978 and 1990. Particular effort is devoted to examining the disparities in these changes among different provinces for respective grain crops. The study will not, however, examine directly the situation after 1991. One of the reasons is the constraint of data. At the time of writing, there were not enough data to analyse changes in productivity after 1991. Another reason is that since 1991, marketing and pricing reforms have accelerated. The old centrally planned system in grain production is being rapidly replaced by an open grain market. Because the new policies have only been practised for a short time, their impact on grain production is not yet clear.

1.2 Major Issues in the Study

The study will concentrate on five sets of specific issues:

1) <u>Data assessment and the implications for studies of productivity</u>. In China, data absence, inadequacy, inaccuracy and inconsistency often cause difficulties in economic analysis. Of these data problems, the key ones which directly affect the analysis of productivity have been the inaccuracy of the

data for arable land and labour input. Similar problems also exist for other input and output statistices. For example, the lack of component and nutrient value details for fertiliser (both chemical and organic fertilisers) often causes problems in examining the effects of fertiliser changes on output. Identifying the effect of these problems and specifying their implications for studying productivity changes in grain production are essential for carrying out an empirically meaningful analysis.

2) Yield and its role in the growth of grain production. In China, the scarcity of arable land means that increasing grain output must rely primarily on increasing output on the given land, i.e. on increasing yields. Therefore, in studying Chinese grain production, grain yield has always been an important aspect to be considered. In fact, since the reforms began, the increase in grain output has been accompanied by a decrease in total grain sown areas, indicating a crucial role for increasing yields. This study will examine the growth patterns of yields and investigate disparities among provinces for respective grain crops between 1978 and 1990.

3) Input-output relationships in national and provincial production in respective grain crops. This aspect investigates how productivity has changed since the reforms began. By using a production function analysis, the relationship between inputs and outputs in provincial grain production for respective grain crops will be specified quantitatively. This will explain how much of the increased output comes from the contribution of increased inputs and how much of the increased output results from the improvement of productivity.

4) Factors responsible for growth patterns and provincial disparities of productivity. Reform policies and their impact on grain productivity and

provincial disparities will be analysed from the perspective of farmers' responses to various economic incentives. Special attention is given to changes in farmers' economic status and the development of the rural economy. This perspective goes one step further than many previous studies which mainly considered the effect of institutional reforms and prices on changes in productivity.

5) The relative production efficiency of grain production in different provinces for different crops. It is argued that, due to the diversity of the natural environment and socio-economic conditions, differences in the level of productivity are inevitable among provinces. This study will make a judgement of the relative efficiency among provinces in producing respective grain crops on the basis of resource utilisation.

Through this study, the sources of growth in Chinese grain production can be identified in quantitative terms and disparities in productivity in different provinces and for respective grain crops can be explored. The explanation of the causes of these disparities will provide a foundation for assessing policy measures for the further improvement of grain production efficiency.

1.3 Characteristics of the Study and the Economic Significance

This study has four key features: use of household survey data, provincial orientation, disaggregate perspective and economic and geographical integration. These features distinguish it from many previous studies of productivity in Chinese agricultural production.

Most of the analysis in this study is based on rural household survey data, which have only become available in recent years. Partly because of the inadequate information in the official statistics, starting from the early 1980s, several nationwide rural household surveys have been carried out by a number of governmental departments and research institutes. These survey data provide first-hand information about the socio-economic activities of rural households. Compared with other available sets of rural household survey data, the one used here contains the most detailed information about household grain production.[5] Nevertheless, because of its limited distribution, it has not been used in previous studies. Thanks to the cooperation of Chinese colleagues, this study is able to use this data set to analyse changes in productivity and household grain production behaviour. The application of this set of data is not only helpful in gaining an insight into the development of grain production, but is also of significance in identifying some of the problems in previous studies of agricultural productivity caused by using the official statistics. Intensive use of the household survey data is, therefore, one of the distinct features of this study.

Provincial orientation is another distinct feature of this study. China is a country with a vast territory. Great variations exist in natural environments, while socio-economic conditions also differ. Such variations have affected the level of grain production in different areas. Different grain crop varieties have further complicated these variations. In fact, since 1978, changes in grain production have varied significantly by areas and by crops. For example, in Jilin province, grain output increased by 123.78 percent between 1978 and 1990, whereas in the neighbouring province, Liaoning, the output only

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[5] This set of data was provided by the Department of Agricultural Policy and Law, the Ministry of Agriculture in China. The survey was organised by the State Price Bureau in co-operation with the Ministry of Commerce, the Ministry of Forestry, the Ministry of Light Industry and several other departments. It covered 30 provinces and more than 15,000 households. For the details of this survey, see Appendix 6.A in this thesis.

increased by 33.81 percent during the same period (SSB, *ZTN*, 1991). With respect to the individual grain crops, between 1978 and 1990, the national output of wheat increased by 82.45 percent, whereas rice only increased by 38.27 percent (SSB, *ZTN*, 1991). These variations underline the different magnitude of changes in productivity in different areas and grain crops during the reform period.

Since the reforms began, the relaxation of the central control over agricultural production has allowed provincial governments greater freedom to make grain production plans and to set prices for grain purchases and grain producer goods. Provincial grain production has been, therefore, strongly affected by provincial government policies. The disparities at the provincial level have become substantial. This has made studies at provincial level both significant and necessary.[6] For this reason, in this study, analysis of the productivity of grain production will be conducted at both the national level and at the provincial level.

A disaggregate approach is also an important feature of this study. The analysis focuses on the three dominant grain crops: wheat, rice and corn, and examines their changes and variations during the period studied. The significance of the disaggregate approach derives from the great disparities between grain crops in terms of spatial distribution, genetic yield, consumption preference, the level of government supervision and the possibility of substitution. Disparities in all these aspects will inevitably create variations in the level and growth of output, yield and productivity among different grain crops. Distinguishing these variations is essential for

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[6] Further discussion of regional issues will be presented in Chapter 3, in which, the different definitions of regions used in various studies and their shortcomings in studying regional grain production in China will be examined.

understanding the mechanisms of the growth and the causes of the disparities in provincial grain production during the reform period.

In Chinese official statistics, grain output refers to unmilled grain, including wheat, rice, corn, soybean, potatoes, millet, sorghum, and other miscellaneous crops.[7] Of these grain crops, rice, wheat and corn account for more than 86.1 percent of total grain output and 75.1 percent of total grain sown area (SSB, *ZTN*, 1991, p.342 and p.346). They are defined as the major grain crops. Other grain crops are, therefore, the non-major or miscellaneous grain crops. The three major grain crops dominate China's grain production. There are relatively adequate data available for these three crops in both official statistics and in many research surveys. Other grain crops are much less significant. In this study, they are classified into one category, miscellaneous grain crops, and are examined as a whole whenever the data are available.

The fourth characteristic of this study is the integration of perspectives and methodologies of economic and geographic disciplines into the analysis of growth and provincial disparities in grain production. It is argued that, under the given level of technology, the impact of the natural environment on the level of productivity is substantial. This is due to the fact that grain production is an activity involving a close interaction with the environment. Soil, climatic, topographic, hydrological and biological conditions combine together to exert a major impact upon farm operational systems and upon the profitability of grain production. Although many of the developments of technology which have taken place have been intended to overcome the limitations imposed by natural factors, the influence of these effects

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7 Potatoes are converted to grain equivalent at a ratio of five kilograms of potatoes to one kilogram of grain.

nevertheless remains (Briggs and Courtney, 1985). Unfortunately, in previous studies of Chinese agricultural productivity, the effect of natural environments on provincial disparities has not been given enough attention. Until recently, there has been little research considering the effect of the natural environment on provincial disparities in the productivity of grain production. This study attempts to devote some effort to this aspect.

1.4 Structure and Content of The Thesis

This thesis consists of 10 chapters. It begins in Chapter 2 with a outline of the theoretical definitions and the methodological issues involved in the study of productivity. This is followed by a literature review of studies of productivity in Chinese agriculture done by western scholars as well as by Chinese economists. The purpose of this review is to examine the contributions, limitations and problems of previous studies of productivity of Chinese agricultural production. On the basis of this examination, the issues needing to be clarified and further analysed in this study will be highlighted. Chapter 3 comprises a discussion of regional issues in studying grain production and a specification of some concepts to be used in the succeeding chapters. It aims to stress the suitability and necessity of conducting a study of provincial grain production, as well as clarifying some conceptual issues which often cause confusion in Chinese agricultural production studies. Chapter 4 is an overview of the growth in grain production between 1978 and 1990. It investigates the growth patterns of national and provincial production with respect to individual grain crops. This chapter aims to provide a general picture of the situation in grain production during the reform period. The key issues to be analysed in the later chapters will be raised.

Chapter 5 analyses grain yield changes and provincial disparities. It first investigates the relationship between grain output and yield growth and then examines the impact of natural environments on the spatial distribution of different types of grain crops and the influence on the levels of provincial grain yields. This investigation will not only demonstrate the important role of increasing grain yields in Chinese grain production, but will also stress the significance and necessity of considering the differences between individual grain crops in comparative studies of provincial grain production.

Chapter 6 estimates production functions for wheat, rice and corn. The main task of this chapter is to determine the weights for computing aggregate inputs, which are the basis of the examination of sources of growth. It also examines the disparities in the elasticities of inputs for different grain crops and discusses the implications of these disparities for the potential growth of individual grain crops. Chapter 7 computes the total factor productivity index and investigates the sources of yield growth. On the basis of this calculation, the performance of grain production in different provinces and of individual grain crops during the period studied can be quantitatively specified. In Chapter 8, the analysis concentrates on exploring farmers' grain production responsiveness to the changes in the broad economic situation in the rural areas and the changes in their own economic status. The implications for further improvement of productivity under the reformed rural institutional system will be underlined.

Chapter 9 investigates the relative efficiency of provincial grain production on the basis of a comparison of yields and levels of productivity of respective grain crops. It also discusses the effect of relaxation of central controls over grain production and the role of provincial governments in utilising resources and in the further improvement of the efficiency of provincial grain production. Conclusions and the implications of the whole study are presented in Chapter 10. This summarises the major findings in the thesis. Some policy options for provincial grain production adjustment and the implications for future development in the 1990s will also be raised.

Chapter 2

Theoretical Notions of Productivity and Empirical Studies of China's Agricultural Production

2.1 Introduction

The study of productivity is one of the basic themes of economics. It is used to specify the relationship between inputs and outputs and to indicate production performance. Productivity growth is closely related to technological progress and improvement in technical efficiency. In the process of production, either technological progress or improvement in technical efficiency will result in a larger output with a given amount of inputs.

This chapter consists of 6 sections. Section 2 outlines the theoretical notion of productivity. Section 3 examines the functional forms for measuring productivity and the economic definition of the elements involved. This is followed by a brief review of studies of labour and land productivity in China's agricultural production in Section 4. Section 5 reviews the literature on total factor productivity in Chinese agricultural production by scholars both within China and abroad. The significance, limitations and problems of these studies will be analysed. Issues requiring further analysis and consideration, will be summarised in Section 6.

2.2 Partial Productivity and Total Factor Productivity

In general terms, productivity measures the physical volume of output that is achieved from a physical volume of inputs (Blandy, et al, 1984). Due to the different nature of each input, there are as many productivity measures as the number of classes of inputs (Salter and Reddaway, 1966).

The oldest and most commonly studied measure of productivity is labour productivity, which refers to output per labour unit or per person-hour. Given the price of the product, labour productivity becomes one of the important determinants for the wage paid to labour and the profits made by employers. For this reason, labour productivity is one of the most common topics studied in western economics.

As economists have pointed out, however, labour productivity does not measure anything peculiar to labour. It should not be considered as the productivity of labour alone (Blandy, et al 1984, p.8). This is because changes in labour productivity can be the result of a variety of factors, including improvements in technology, increases in inputs and increases in labour efforts, as well as the enhancement of management.

Similarly, land productivity measures the output per unit land. Again, land productivity does not measure the productivity of land alone because changes in land productivity can be the result of changing labour and material inputs, as well as technical and efficiency changes other than an improvement in the quality of the soil (although this may happen in the process of production). Nevertheless, the concept of land productivity is of significance in practice. It is particularly important in countries where land resources are scarce. In such countries, limited land resources means that increasing output has to rely primarily on increasing land productivity or output per unit of land. In fact, agricultural development in many Asian countries has been tracing this path (Hayami and Ruttan, 1985).

Labour productivity and land productivity measure the ratio of output to specific inputs: labour and land, respectively. They are thus defined as partial productivity (Fan Shenggen, 1990). As changes in labour and land productivity can be attributed to a variety of factors other than changes in the capability of labour and land themselves, partial productivity provides little information about the specific sources of change, in particular, changes in technology and efficiency. The limitations of partial productivity in practice leads to the study of total factor productivity. According to the definition, total factor productivity measures the output achieved from all associated inputs. The consequence of total factor productivity growth is an increase in output per unit input, or a reduction of input per unit output. Conversely, total factor productivity decline results in a decrease in output per unit input or an increase in input per unit output.

The measurement of total factor productivity has the following properties: 1) it reflects the aggregate efficiency of all factors involved in production; and 2) the volume of total factor productivity is a dimensionless notion (Heathfield, 1971, 31). The merit of this concept is clear. On the one hand, it evaluates the overall performance of production, and on the other hand, its dimensionless measure provides an empirical way to compare production performance among different production processes and during different periods.

It is worth pointing out that in some studies, the term productivity is often used interchangeably with the term total factor productivity (see for example, Solow, 1957; Kendrick, 1961; Blandy, et al, 1984, Lin Yifu, 1992). To avoid any confusion, the following study uses the term total factor productivity to distinguish it from labour and land productivity.

2.3 Measurement of Total Factor Productivity

Total factor productivity measures the relationship between aggregate inputs and output. It reflects the technology used and the efficiency achieved in production. In the process of measuring total factor productivity, assigning weights to each input is the first task that needs to be done. The weights represent the relative importance of different types of input units for the output. Obviously, determining the appropriate weights for each input is essential for measuring total factor productivity. In practice, there are two standard ways of estimating the weight of individual inputs and total factor productivity in agriculture. One is the production function approach. The other is to add up individual input series using value weights based on the prices of the various inputs (Perkins and Yusuf, 1984, p.46). In studying Chinese agricultural productivity, the most commonly used method is the production function approach.

The theoretical development of production functions has been closely linked with the empirical work. The wide application of computer techniques in economic studies has also facilitated this development. There are many functional forms used in production function analysis, including Box-Cox, Generalised Leontief, Generalised Quadratic, CES, Cobb-Douglas and Translog. The choice of the production function form is determined by various factors, including the nature of the production process studied, the level of details required, and the availability of data. However, as Fan Shenggen (1990) pointed out, although the more general forms often have more variables and fewer restrictions, they require more data and may lead to some econometric estimation problems, such as multicollinearity. Therefore, in practice, their application is often restricted. This section reviews two of the most commonly used forms of production function: the Cobb-Douglas and the Translog.

2.3.1 The Cobb-Douglas Production Function and Its Development

The basic Cobb-Douglas production function in agriculture is formed as follows:

$$Y = AK^{\alpha}L^{\beta}S^{\gamma} \qquad (2.1)$$

where Y = output,

K = capital,

L = labour,

S = land,

and A and α, β and γ are parameters.

The dimensional consistency between the two sides of the production function equation (2.1) is achieved through the constant A (Heathfield, 1971, p.31). The restriction of a constant elasticity of substitution of unity is imposed in this form, and the aspect of dynamic changes in technology is not embodied. Analyses are thus concerned only with static production and distribution. To make it suitable for long-term analysis, during which period technologies may change, a development of the Cobb-Douglas production function was to recognise that the set of all known production techniques may expand over time. Therefore, a time trend is adopted to embody the process of technical progress. The form of the Cobb-Douglas production function then becomes:

$$Y = Ae^{rt}K^{\alpha}L^{\beta}S^{\gamma} \quad (2.2)$$

or in logarithm form:

$$Ln(Y) = a_0 + rt + \Sigma a_i Ln(X_i) \quad (2.2)'$$

where the rt represents neutral technical progress. X_i is the i^{th} input. a_i is the output elasticity with respect to i^{th} input. In form (2.2)', the restriction of constant elasticity of substitution of unity is maintained, but it allows technical progress to occur as a time trend. This kind of technical progress is neutral and does not affect the elasticity of substitution.[1]

Accommodating neutral technical progress in the Cobb-Douglas production function widened its application. However, the restriction of constant elasticity of substitution of unity can still be a shortcoming for a study involving a long period of time. This is because the development of technology is closely related to factor endowments for a particular country or individual sector. The path of technological development may have an impact upon factor substitution. A typical example would be that of China. Due to the fact of land scarcity and labour abundance, efforts at technological improvement have been concentrated on saving land through increasing yield. In this case, the restriction of constant elasticity of substitution of unity imposed in the Cobb-Douglas production function would be challenged by such a bias in technological development. However, for a study involving a short period of time, using the Cobb-Douglas production function may not

[1] For the details of this neutrality, see Heathfield (1971, p.42) and Ferguson (1969, p.242).

cause a serious problem in estimating changes in total factor productivity (Fan Shenggen, 1990). This is one of the reasons for the wide use of the Cobb-Douglas production function.

2.3.2 Flexible Functional Forms - the Translog Production Function

Over the past two decades, more general and more flexible production functional forms have been introduced to relax the restriction of the constant elasticity of substitution. One of the most widely used forms is the Translog production function. This form can be specified as follows:

$$\begin{aligned} Ln(Y) &= \underset{(1)}{a_0} + \underset{(2)}{a_t t} + \underset{(3)}{\sum_i a_i Ln(x_i)} + \underset{(4)}{\sum_i a_{it} Ln(x_i) \times t} \\ &+ \underset{(5)}{\sum_i \sum_j a_{ij} Ln(x_i) \times Ln(x_j)} + \underset{(6)}{a_{tt} t^2} \end{aligned} \qquad (2.3)$$

where Y is the output, x_i is the i^{th} input and t is the time trend. Assuming that the production function is linear-homogeneous in inputs, then the constraints imposed are:

$$\sum_i a_i = 1;$$

$$\sum_i a_{ij} = 0; \text{ for all j;}$$

$$\sum_i a_{it} = 0.$$

Compared with the Cobb-Douglas production function, the Translog form has three additional terms (4), (5) and (6). They represent the effects of biased technical change,[2] interaction between inputs, and the uneven progress of neutral technology, respectively.

The production function represented by the Translog form shown above is rather ideal. In practice, serious multicollinearity problems often occur, resulting in biased estimates. To avoid this problem, some of the elements in the formula are often dropped, subject to maintaining maximum information and as much accuracy as possible in the result.

For a production function involving a short time period, the change in technology may be not significant. In this case, elements relating to technical change can be dropped. The Translog form then becomes

$$Ln(Y) = a_0 + \sum_i a_i Ln(x_i) + \sum_i \sum_j a_{ij} Ln(x_i) \times Ln(x_j) \qquad (2.4)^3$$

With the restriction that all inputs are independent or separable, form (2.4) becomes a Cobb-Douglas production function:

$$Ln(Y) = a_0 + \sum_i a_i Ln(x_i) \qquad (2.5)$$

In a production process which involves a long time period, however, technical change may play an important role. Therefore the elements relating to technical change in form (2.3) would need to remain. The element

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2 Unlike neutral technology which shifts the isoquant of the production function, biased technological progress changes the shape of the isoquant. In this case, the elasticity of substitution will be changed.

3 This form has been used by Kalirajan (1991).

representing interactions between inputs, however, may have to be dropped to avoid statistical problems. The translog form (2.3) can then be specified as:

$$Ln(Y) = a_0 + a_i t + \sum_i a_i Ln(x_i) + \sum_i a_{it} Ln(x_i) \times t + a_{tt} t^2 \qquad (2.6)^4$$

The translog production function allows the restriction of constant elasticity of substitution to be relaxed. Due to the flexibility the form possesses, it has been widely used in recent years. However, multicollinearity is also a problem which often restricts its application.

2.3.3 Total Factor Productivity Index

Total factor productivity is the ratio of output over the weighted sum of inputs. Therefore, given the weights of inputs, it is necessary to determine the formula for calculating the aggregate inputs and total factor productivity. In practice, there are several ways to do so.[5] However, the methods used most often in empirical studies have been Kendrick's arithmetic index (Kendrick, 1961) and Solow's geometric index (Solow, 1957).

The formula for the Kendrick's arithmetic index can be expressed as follows:

$$I_t = \frac{Y_t / \sum_i S_i X_{it}}{Y_0 / \sum_i S_i X_{i0}} \qquad (2.7)$$

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[4] This form has been used by Fan Shenggen (1990).

[5] For the detailed discussion of the methods for measuring total factor productivity, see Fan Shenggen (1990) and Lovell and Tatje (1994).

where Y_t is the total output at the year t, X_{it} is the i^{th} input at the year t, S_i is the factor share of the i^{th} input, Y_0 is the total output in the base year, X_{i0} is the i^{th} input in the base year and I_t is the arithmetic index for the year t.

Because of the simplicity of the arithmetic index, it has often been used in previous studies of China's agricultural productivity.[6] However, the greatest disadvantage of the arithmetic index is the linear aggregation of inputs, implying that the elasticity of substitution among inputs is infinite (Fan Shenggen, 1990, p.79).

Solow's geometric index is based on the Cobb-Douglas production function with constant returns to scale and neutral technological change. Consider a Cobb-Douglas production function as:

$$LnY(t) = LnA(t) + \sum_i S_i \times LnX_i(t) \qquad (2.8)$$

where S_i is the output elasticity with respect to the i^{th} input. By taking the first differential, it becomes:

$$\partial A(t) / A(t) = \partial Y(t) / Y(t) - \sum_i S_i \times \partial X_i(t) / X_i(t) \qquad (2.9)$$

where $\partial A(t)/A(t)$ is the production function shift rate, which indicates the growth rate of total factor productivity.

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6 This method has been used by Feng Haifa (1987), Tian Weiming (1987) Stavis (1990) and Wen Guanzhong (1993).

The difference between a geometric index and an arithmetic index is that the former is non-linear whereas the latter is linear. Some economists believe that where the changes are small, the differences between the two measures are negligible. However, in rapidly developing economies, the differences may be sizeable enough to affect conclusions drawn from the data (Kleiman, et al, 1966 and Chow, 1985). So far, the technical debate over the suitability of these two indexes remains unresolved. It is not the intention of this study to explore this issue in detail. As the following analysis applies the production function approach in estimating total factor productivity, the geometric index will be used.[7]

2.4 Studies of Labour and Land Productivity in China's Agricultural Production

In the study of agricultural production, labour and land productivity are two key topics. In China, studies of these two aspects have been strongly influenced by China's basic characteristics, the scarcity of arable land and the huge size of the population. This section reviews briefly the major features of studies of labour and land productivity in Chinese agricultural production.

2.4.1 Surplus Labour vs Labour Productivity

In China's agricultural production, because of the extremely small farm size in contrast to the huge labour force, there were no strong incentives to increase labour productivity in the three decades before the reforms. The pressure of constantly increasing food demand and the strategy of national

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[7] It is acknowledged that both the geometric and arithmetic indexes require an assumption of competitive equilibrium. This assumption, however, may be challenged in studying the Chinese economy since both the pricing and marketing systems there are distorted. Despite acknowledging this problem, the geometric and arithmetic indexes are still widely used in studying total factor productivity in China since there is no better measurement available.

industrialisation led the government to impose barriers to stop agricultural labour shifting to non-agricultural sectors.[8] Increasing labour input was considered an important means to increase output. Labour productivity was almost totally ignored. Apart from this, the income distribution system under the People's Commune also encouraged farmers to increase labour inputs as income was based on the work points a labourer earned but not necessarily the output a labourer generated. Many scholars have pointed out that although the commune was successful in mobilising rural labour in agricultural production, it failed to make efficient use of this labour (Barker, et al, 1982; Perkins and Yusuf, 1984 and Marshall, 1985). This point will be further discussed in Chapter 5 when looking at changes in labour input during the reform period.

Since 1978, a concern for labour productivity has emerged. However, the contradiction between the small area of arable land and the large labour force still remains. This makes it difficult to improve labour productivity. It has been widely accepted that there is a large number of surplus labourers in rural areas at the present (Meng Xin and Bai Nansheng, 1988; Taylor and Banister, 1988; Chen Jiyuan and Geng Dechang, 1990; Liu Fuyuan, 1993; Wu Xiaohua, 1993; Zhu Ze, 1993; Du Ying, 1994; Guo Shutian, 1994b). Unless these labourers can shift to other sectors, increasing labour productivity is unrealistic. For this reason, studies directly examining changes in labour productivity in agriculture, and in particular in grain production, are rare.[9] Instead, the focus is on the issue of shifting surplus labour to non-agricultural sectors. A large number of studies have been done in this area in recent

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8 There were other reasons for this policy. For example, preventing farmers moving to cities could ease the pressure of increasing rationed grain supply to urban residents, reduce unemployment and alleviate the burden on urban infrastructure and facilities.

9 However, in some previous studies, the effects of reforms on labour productivity have been mentioned. This can be seen in Andrew Watson (1987) and Tian Weiming (1987).

years.[10] Further consideration of the details of these studies, however, lies beyond the scope of this study.

2.4.2 Land Productivity and Output Potential

In contrast to the few studies of labour productivity, land productivity has been widely considered in China both before and after the reforms. This is, of course, closely related to the persistent pressure of population against scarce arable land. This pressure has become even more intensified during the reform period, when cultivated land has declined constantly. For this reason, the issue of land productivity or yield has attracted much attention, and it is impossible to review all studies here. A common opinion in most of the studies, however, has been that the increase in land productivity both in the past and in the future has had to and will still have to rely primarily on increasing inputs and improving "land-saving technology"[11]

Apart from the direct study of improving land productivity or yield, the increasingly heavy population pressure on the declining area of cultivated land has led recent studies of land productivity to incorporate concern about the population-bearing capacity of land. Work on this issue has been done by the Statistical Bureau of the Ministry of Agriculture (1987), Zhang Yuerong and Huang Yaohui (1990), the Chinese Academy of Agricultural Sciences (1991), Li Shengru (1992) and the Comprehensive Survey Team of the Chinese Academy of Sciences (1992).

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[10] Apart from the references mentioned above, some other studies of labour transfer have been done by Zhu Yaqing (1989), Yang Tiao and Cai Fang (1991), and Harry Wu (1992).

[11] The term land-saving technology is from Hayami and Ruttan (1985) in their study of the development of agriculture.

Despite the large number of studies, few have explicitly analysed regional disparities in land productivity or grain yields in the context of an integrated view of the impact of the natural environment, the genetic characteristics of grain varieties and socio-economic conditions. Regional studies of grain production often focus on the aggregate yield. As a consequence, regional disparities cannot be adequately explained.

2.5 Review of Studies of Total Factor Productivity: Significance, Limitations and Problems

As mentioned previously, studies of total factor productivity in Chinese agricultural production were rare before the 1980s. Most of the work on this issue has been done only in the last 10 or so years. This section first reviews some of the studies undertaken by western and Chinese scholars regarding the productivity, technology and efficiency of Chinese agricultural production. It then comments on the results of these studies and highlights the issues that will be addressed.

2.5.1 Review of Studies of Total Factor Productivity in Chinese Agricultural Production

Despite acknowledging the rapid increase in the application of modern inputs such as fertiliser, electricity and machinery and noting a reasonable growth rate of agricultural production during the 1960s and 1970s, Wiens (1982) raised doubts concerning the significance of technical progress in Chinese agricultural production. He pointed out that, unlike statistics which detail increases in inputs and output, technology "is defined as a set of practices that determine the quantitative and qualitative relationship between inputs and outputs". Wiens argued that the distinction may be "muddy in practice, but it is clear-cut in theory". The increasing use of modern inputs is not what economists normally mean by technical progress. Nevertheless, he did not deny that there may have been some technological progress in Chinese agriculture after the founding of the People's Republic. As far as Wiens was concerned, China's multi-cropping index could not have increased so substantially without technological progress.

Wiens estimated changes in total factor productivity between 1957 and 1978. The weights assigned for aggregate inputs were based on estimates of the relative marginal productivity in 1957. The weight for labour was 0.35, for land 0.36, for capital 0.09 and for current inputs 0.20. Using these weights, the result shows that total inputs grew less rapidly than total output. Wiens considered this difference as the improvement in technology (and/or management). The increase in productivity estimated on the basis of these weights was 19 percent between 1957 and 1978. However, Wiens was also aware of the questionable reliability of the estimation and pointed out that the results of this kind of exercise are very sensitive to the choice of weights, and therefore, should not be taken too seriously (Wiens, 1982, p.100).

Compared with Wiens, the study done by Perkins and Yusuf (1984) focuses on elaborating the sources of agricultural growth in China, in particular, on components affecting total factor productivity. They point out that there are two levels at which the question of how to raise agricultural output can be addressed. The first level is the direct inputs into production, such as land, labour, and various forms of capital. This level is further divided into two elements: input contribution and the productivity of those inputs. The second level is the organisation of society to mobilise the inputs effectively and to use them efficiently.

In estimating total factor productivity changes in Chinese agricultural production, Perkins and Yusuf point out that market prices are an appropriate estimate of marginal product only under perfect market conditions. However, such an assumption is not valid for labour inputs and much of fixed capital in China. Nevertheless, they estimated total factor productivity by adding up individual input series using value weights based on the average prices of the inputs. They found that between 1957 and 1979, the change in total factor productivity was negative, if a high estimate of the marginal output of labour input is assumed, and 14.7 percent, if a low estimate of the marginal output of labour input is used (Perkins and Yusuf, 1984, pp.67-68). They argued that organisational and institutional systems were the two main factors responsible for the low efficiency of Chinese agriculture. They concluded that output increases in China during this period were achieved at the cost of increasing mismanagement and declining personal incentives.

Although the estimation methods and the mathematical forms that Wiens and Perkins and Yusuf used in their analyses were simple and the data were also crude, the ideas they explored were valuable and significant in the study of Chinese agriculture. Their work has been cited in many of the later studies of Chinese agricultural productivity.

The above pioneering studies of total factor productivity in Chinese agricultural production considered the period before the reforms. Since 1978, there have been fundamental changes in agricultural production. This has attracted many studies of the sources of production growth and the impact of reforms on total factor productivity changes.

One of the early studies of agricultural productivity was done by Feng Haifa (1987). Using the Cobb-Douglas production function, he estimated output elasticities with respect to land, labour and capital in Chinese agricultural production between 1952 and 1985. The result showed that the elasticities of each input were 0.25, 0.28 and 0.47, respectively. He then applied these elasticities as weights to compute the aggregate input so as to estimate the index of total factor productivity during this period. According to Feng, total factor productivity increased modestly over the years. Between 1981 and 1985, the annual growth rate of total factor productivity was only 0.88 percent. During this period, the contribution of total factor productivity increase accounted for 8.3 percent of total agricultural growth and the remaining 91.7 percent was attributed to the increase in inputs.

Another early approach to the issue of agricultural productivity was that of Tian Weiming (1987). Tian also used the Cobb-Douglas production function to estimate the differences in labour productivity and total factor productivity among 29 provinces during the period 1981 to 1984. The result showed that total factor productivity was relatively higher in the developed coastal areas than in the less developed inland areas. Taking the country as a whole, the average growth rate of total factor productivity was 6.4 percent annually, which was much higher than Feng's estimation.

The impact of the reform policies on total factor productivity has become an important issue during the later years of the reforms. McMillan, et al (1989) studied the effect of the implementation of the Household Responsibility System (HRS) and the increase in the purchase prices for agricultural products on agricultural production between 1978 and 1984. The weights they assigned for each input factor were 0.25 for land, 0.5 for labour, 0.1 for capital and 0.15 for current capital. These weights were quoted from

Anthony Tang's (Tang and Stone, 1980) estimation based on the factor shares in 1952. As far as McMillan, et al, were concerned, in 1952, when the government had not yet imposed control over agricultural production and marketing, factor shares were determined by competitive market forces. Using these weights, McMillan, et al, estimated that between 1978 and 1984, the total factor productivity of agriculture increased by 41 percent. Of this increase, 32 percent was induced by the incentive effects of the implementation of the HRS and 9 percent was from the increase in prices.

Stavis (1991) examined the market reforms and changes in agricultural productivity during the reform period. According to his estimation, output elasticity for chemical fertiliser was 0.49, and for labour it was -0.06. Stavis concluded that chemical fertiliser input was the most important factor in agricultural production. The negative sign for labour input meant that rural China had an adequate labour pool, and the return for increasing labour input was negligible. His result also showed that from 1980 to 1984, average crop productivity in China went up 3.7 percent annually, which gave a 15.64 percent increase in total factor productivity during this period. Between 1985 and 1989, the annual growth rate of total factor productivity dropped to -2.5 percent, indicating that during this period, total factor productivity decreased by 10.38 percent. Therefore, the average increase in total factor productivity between 1980 and 1990 was only modest.

In recent years, a number of Chinese economists who have studied in western countries have used western productivity theory in Chinese agricultural productivity studies. One of the most influential studies was done by Lin Yifu (1992).[12] The agricultural production function he used was a

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12 The initial draft of this study was completed in 1989 and published in the working paper series of the Research School of Pacific Studies (RSPacS), at the Australian National University.

Cobb-Douglas form with four conventional inputs, namely land, labour, capital, and chemical fertiliser. In addition, he also considered six non-conventional variables, including the percentage of teams using the HRS, the market price index, state purchasing prices, the percentage of sown area in non-grain crops, a multiple cropping index, and a time trend. According to Lin Yifu, these six variables were incorporated to assess the impacts of institutional change, price adjustments, market reforms, and technological changes on productivity.

Lin Yifu used the data for 1965 and 1970-1987. The estimated elasticities with respect to each input were 0.67 for land, 0.13 for labour, 0.07 capital, and 0.19 for chemical fertiliser, respectively. Based on estimated parameters, Lin Yifu calculated that between 1978 and 1984, the effect of the institutional reforms explained 48.6 percent of the output growth. Of this growth, 96 percent could be attributed to the change in farming institutions from the production team system to the HRS. The other 4 percent was attributed to the combined effects of increases in market prices, and changes in cropping patterns and cropping intensity. In Lin's study, the contribution of productivity growth to total agricultural growth during the early 1980s was much more significant than in the other studies mentioned above.

One of the most sophisticated studies of productivity issues is Fan Shenggen's (1990) work. He used a translog form of production function to estimate land, labour and total factor productivity in agricultural production at both national and regional levels, and computed the contributions of factor inputs, technology and technical efficiency to growth. The estimated coefficients for conventional inputs in Fan's study are 0.36 for land, 0.28 for labour, and 0.24 for chemical fertiliser, which are different to Lin's. In accounting for the contribution of inputs to the production growth, Fan's result showed that between 1965 and 1986, 70 percent of growth could be explained by input increases, and the remaining 30 could be attributed to the growth of total factor productivity.

Agricultural production is conducted in an open environment. Periodic fluctuations in weather conditions can cause fluctuations in agricultural production. Consequently, this may affect the results of production function estimates. However, due to the complexity of weather conditions and the constraints of data, studies which consider weather effects in estimating production function are few. Zhang Bin and Colin Carter 's study (1993) can be seen as one of the pioneering efforts in this area. In their study of the effects of economic reforms on China's grain production between 1980 and 1990, they used disaggregated county-level production data, and the weather factor was explicitly specified in the model. The result claims that the institutional impact of the economic reforms accounted for about 25 percent of the production growth, which is smaller than the estimations in many other studies, such as Fan Shenggen (1990) and Lin Yifu (1992). Zhang and Carter argued that this was because in these studies, the effect of weather fluctuations was wrongly included into the effect of reform policies. They considered that the good weather conditions were partly responsible for the rapid increase in grain output during the early 1980s.

There are several other studies of total factor productivity of Chinese agricultural production. The results are generally different from the above studies. For example, a study carried out by the Chinese Academy of Agricultural Science (edited by Liu Zhicheng, 1990) shows that during the period 1978 to 1986, total factor productivity increased by 24.4 percent, which accounted for approximately 36.6 percent of agricultural growth (Liu Zhicheng, 1990, pp.337-338).

Zhu Xigang (1991) studied technical progress in grain production using a Cobb-Douglas production function. Zhu's estimation of the contribution of technical progress and inputs to grain output growth between 1979 and 1986 was 32.7 percent from technical progress and 44.4 percent from increased inputs, and the remaining 23 percent represented the contribution of the improvement in technical efficiency induced by the rural institutional changes.

It needs to be pointed out that except for Zhu Xigang (1991), all the studies reviewed above have generally been concerned with agricultural production or aggregate grain production as a whole. Until recent years, studies of disaggregated grain productivity have been extremely rare.

2.5.2 Comments on the Previous Studies

In the studies of total factor productivity reviewed above, a prominent feature is that the weights given for computing aggregate inputs are quite different, resulting in varying estimates of total factor productivity. In order to observe these differences more clearly, Table 2.1 summarises some of the results from the previous studies. It shows that the weight for land input ranges from 0.25 in Feng and McMillan et al to 0.67 in Lin. Nevertheless, for all the authors, the weight for land input is relatively large compared with other inputs.

Table 2.1 Output Elasticities of Factor Inputs in Selected Previous Studies

	Wiens (Wen)[a]	Feng	McMillan et al (Tang)[b]	Fan	Stavis	Lin	Zhang & Carter
Scope[c]	Agri(+)	Agri(+)	Agri(+)	Agri	Agri	Agri	Grain
Method	Denison-Solow Accoun-ting	C-D	Value share	FP[d]	C-D	C-D	C-D
Period	57-78	52-86	78-84	65-86	80-89	70-87	80-90
Land	0.36	0.25	0.25	0.36	0.46[e]	0.67	0.44
Labour	0.35	0.28	0.50	0.28	-0.06	0.13	0.23
Chemical fertiliser				0.24	0.49	0.19	0.20
Capital	0.09	0.47	0.10			0.07	
Current capital	0.20		0.15				
Draft animals				-0.13			
Irrigation				0.06			0.14
Machinery				0.06	0.11		0.03
Time trend				0.01	0.004	0.003	0
Growth of total factor productivity	19.0	16.7	41.0	23.6	3.66	39.2	n/a

Note:
a. Wiens's weights were also used by Wen Guanzhong (1993) in studying the effect of the reforms on agricultural production.
b. McMillan et al used Tang's weights which were estimated on the basis of 1952 market prices.
c. Agri(+) refers to the broad view of agriculture, including crop farming, forestry, animal husbandry, sidelines and fishery. Agri refers to the crop farming sector, including grain and cash crops. Grain refers to the grain sector only.
d. The Frontier production function.

e. Stavis' production function was established on per unit of land. Here, the elasticity of land input is derived from 1 minus other input coefficients based on an assumption of constant returns to scale.

The differences in the output elasticity of labour input are also large. For example, in McMillan et al, the weight of labour input is 0.5, whereas in Stavis's study, it is a negative figure. These differences cause some confusion in understanding the effect of labour input on agricultural production. As far as McMillan et al are concerned, increasing labour input has a significant and positive effect on agricultural growth, and for Stavis, increasing labour may reduce the output.

Apart from land and labour, the other types of inputs considered by different scholars varied significantly. The definition and the scope for these inputs also differed. It is therefore difficult to compare the weights among different studies. A commonly considered input is chemical fertiliser, which is regarded as an independent variable. Comparing the results among Fan Shenggen, Stavis, Lin, and Zhang Bin and Carter, however, it is seen that the coefficient for chemical fertiliser differs markedly. As for the other inputs, no common characteristics can be found, except that they are all generally small.

Because of the different weights given by different scholars, the variations in aggregate input index are to be expected. As the total factor productivity index is the ratio of output to the weighted aggregate input, it is not surprising that the estimated total factor productivity growth is also different.

The questions needed to be asked here are: why were the weights given by scholars so different? And what are the implications of these differences for productivity studies of Chinese agricultural production?

Before investigating total factor productivity changes in grain production in this study, these questions need to be answered.

First of all, the periods studied were different. This is certainly one of the reasons for the different weights. It is widely recognised that there has been significant technological progress over the last three or four decades (Wiens, 1982; Perkins and Yusuf, 1984; and Stone, 1988b). Because of the scarcity of arable land, this progress has been strongly biased towards "land saving" technology (Fan Shenggen, 1990). This point may be part of the reason for the small or insignificant coefficient of time trend in the studies by Stavis, Lin, and Zhang and Carter, which indicates that neutral technological progress was not significant. The biased technological progress meant that the weights or output elasticities of inputs would not have been constant over time. For this reason, because McMillan et al, use Tang's weights based on the estimation of market prices in 1952, their results may not be reliable in explaining the growth of total factor productivity and the effects of reform policies on agricultural production during the period 1978 to 1984.

Apart from the effects of the differences in the periods studied, the different scopes of the studies may also be responsible for the variations in the weights. The broad concept of agriculture was used by Wiens, Feng and McMillan, et al. In Fan, Stavis and Lin's studies, however, "agriculture" referred to the narrow concept. Zhang and Carter's study considered aggregate grain production. Because of the different scope and content, the different weight for each input in different studies is to be expected. The implication of this is that it is inappropriate to compare the coefficients or weights estimated in different studies with different scopes, or to use them as the basis for further studies which do not have the same definitions.[13]

[13] This issue will be discussed further in Chapter 6.

There are also other reasons for the variations of weights among different scholars. A most obvious one is that the data for labour input are often problematic. This is because that in Chinese official statistics, only the total number of agricultural labourers is provided.[14] There is no separate category for labour input in either crop farming or grain production.[15] This is related to the fact that Chinese farmers are generally involved in multiple activities. It is very difficult to provide a clear cut definition of the occupation of individual farmers. In previous studies of total factor productivity, the share of the output value of a sector in rural gross output value was often used as a weight to estimate the labour input in this sector. This method was used by Lin Yifu (1992), Fan Shenggen (1990), and Zhang Bin and Colin Carter (1993). In the absence of reliable official data for labour input in individual sectors, this method can be considered as a compromise. However, as this method involves product prices and, in China, product prices have long been distorted, it may cause some problems in estimating the coefficient of labour input.

In addition to the above problem, the existence of surplus labour has made the estimation of labour input in each sector more difficult. For example, using the value share method to estimate labour input always shows an increasing number of labourers in the crop farming sector and the grain sector during the reform period. In contrast to this result, several household surveys collected in last 10 or so years have shown a decrease in actual labour input in the crop sector and grain production (SPB, *QNCSZH*, 1981-1991; ECCAY, *ZNN*, 1984-1991). Therefore, the method of using the

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14 Here, total agricultural labourers refer to the labourers in agriculture broadly defined to include crop farming, forestry, animal husbandry, sidelines and fishery.

15 In official statistics, labour input in the crop sector has only become available since 1988.

value share to estimate the labour input share may lead to biased results in the estimation of total factor productivity.

Table 2.1 also shows that, apart from land and labour, the other input factors considered varied in different studies. This reflects the differences among scholars in classifying various inputs. For example, in Feng's study, capital input includes all expenditures except for land and labour. Whereas in Wiens and McMillan et al, capital was divided into fixed capital and current capital. In other studies, capital was further divided into several specific categories, mainly including chemical fertiliser, irrigation and machinery. Understandably because of the data constraint, the variables representing capital inputs in Fan, Stavis, and Zhang and Carter ignored the application of seeds, insecticides and manual and semi-manual tools in agricultural production. It is well-known that by dropping relevant variables, the estimates of the coefficients of those remaining in the equation will be biased (Johnston, 1984). The effects of these ignored capital inputs will be captured by other inputs. This will skew the coefficients of the variables considered, e.g., land and labour, and consequently cause problems in estimating total factor productivity and explaining the contribution of each input to agricultural growth.

Although the effect of weather fluctuations has been recognised by many scholars, studies considering this effect on estimating total factor productivity are rather rare. Only a few studies, including Zhang and Carter, 1993, integrated this factor into their analytical model. As weather conditions can strongly affect the output in a given year, the situation in the initial year and the final year has significant effects on the measurement of the growth of total factor productivity in the period studied. This may be one of the reasons for the different ranges of the growth of total factor productivity in the studies shown in Table 2.1.

The differences among the above studies may also have stemmed from some technical factors, such as the application of functional forms and the expression of dummy variables. It is, however, difficult to discriminate among a variety of functional forms on statistical grounds, since they all involve similar estimation techniques (Appelbaum, 1979).

All in all, divergent results in studies of Chinese agricultural productivity have various causes. What one can at least draw from the above analysis is that reliable estimation of weights for inputs and changes in total factor production requires better data quality and sophisticated explanations of the estimated results.

2.6 Concluding Remarks

Having specified the theoretical notion of productivity and having reviewed previous studies of productivity in Chinese agricultural production, there are two conclusive points that can be drawn here.

The first point is that there seems to be no common agreement among existing productivity studies of Chinese agriculture. In examining previous studies of total factor productivity, it was found that although all results have shown an increase in total factor productivity during the early 1980s, the extent measured has varied significantly. The data problem, particularly the reliability of data for labour input, is certain to have been one of the reasons for this. Another cause of the differences may stem from the variable specifications. This is particularly so for the inputs other than land and labour. Different definitions of variables chosen in functional forms may cause a bias for the coefficients estimated. In previous studies of Chinese agricultural productivity, this issue had not received enough attention.

Second, few studies have focused on productivity in grain production. One of the reasons is the data constraint. In official statistics, data for labour input and capital input in grain production are not available separately. In the few studies of this issue, grain is generally considered as a whole and/or examined at the national level. Regional and disaggregated studies are rare. Yet, grain production is a broad concept and it includes a variety of different crops. Each of them possesses different genetic characteristics, and the spatial distribution and yield of respective grain crops vary significantly. Studies of aggregate grain production are unable to capture these differences and to provide necessary information for regional production adjustment. Obviously, in this area, more work needs to be done.

Chapter 3

Regional Grain Production and Some Conceptual Issues

3.1 Introduction

China's vast size results in great variations in natural and socio-economic conditions. These variations have resulted in significant disparities in agricultural production. Since the rural economic reforms began in 1978, the decentralisation of production management as well as the uneven development of society and the economy have further reinforced these regional diversities. For this reason, since the late 1980s, the variations in regional agricultural production have attracted increasing attention (see, for example, Colin Carter and Zhong Funing, 1988; Fan Shenggen, 1990; Quan Shuren, et al, 1990; Lardy, 1990; Li Qingzeng, et al, 1991; Deng Yiming, et al, 1992). However, the definition of regional identity in these studies is often inconsistent. This has caused some confusion in understanding regional agricultural production. It has also made it difficult for policy makers to stipulate appropriate measures for regional development. Clarifying the concept of "region" and defining appropriate regions are therefore necessary tasks before embarking on a systematic regional analysis of agricultural production. This chapter first discusses the concept of regions and then comments on several commonly used definitions of regions in studies of Chinese agricultural production. On the basis of this discussion, the concept of region most appropriate for the purposes of the present study will be determined.

Apart from the definition of regions, some key terms regarding the rural economy are also often used inconsistently in studies of agricultural production. Data embracing different contents have been used by different authors and, at times, by the same author. Even the term "agriculture" itself has not been satisfactorily defined. This has led to some confusion in understanding Chinese agricultural production and the rural economy. This chapter will clarify some conceptual issues relevant to agricultural production and specify the terms used in this study. In this way, the confusion caused by unclear definitions will be avoided.

Inaccuracy of statistical data is also a common problem in studies of Chinese agricultural production. This is most apparent with respect to arable land area. It has been widely acknowledged that the arable land area in official statistics is substantially underestimated, resulting in an overestimation of yields and/or an underestimation of grain output and the potential for grain production in China. This chapter will conclude by examining some of the reasons for such underestimation and outline the effects of such inaccuracies on this study.

3.2 Definition of Regions and the Significance of Provincial Studies

Diversities in natural environments and socio-economic conditions have shaped the characteristics of agricultural production in different regions. However, because there is no standard definition, the concept of region has varied from one study to another. This section aims to clarify this concept.

3.2.1 The Definition of a Region

Generally speaking, a region is defined as an area that can function independently, although it can have strong links with the rest of the national economy. A region also has a cohesiveness that is historically based. Therefore, a region may be understood as a time dimension over a space (Richardson, 1979, p.1-3). Nevertheless, there is no unique criterion in defining the notion of a region. In practice, the choice of definition depends upon the objectives of the inquiry.

In classical regional theory, there are three types of regions: homogeneous regions, nodal regions and planning regions (Richardson, 1979, p.19). The **homogeneous region** implies that areas cohere together to define a region if they are homogeneous from the point of view of sharing predetermined key criteria. The shared characteristics can be economic (e.g. similar per capita incomes, a dominant industrial sector common to all sub-areas, or uniform unemployment rates); geographical (similar topography and climate, a common natural resource); and socio-political (a common historical development, or allegiance to a particular political ideology). The **nodal region** concept deals explicitly with what happens within regions and treats the spatial dimension as important. Within regions, there are dominant cities (nodes) and within cities, there are nuclei that form business and social centres. The intensity of population and industries agglomerates in cities and declines over distance. The nodal region is often used in studies of population and industrial distributions. The **planning region** is an area over which economic decisions and policy instruments apply, and this is its sole unifying force. The planning region is mainly practiced in planned economies, where the country is divided into several parts to fulfil national economic objectives and to provide the area base for regional economic administration.

The above three types of regional concepts serve different purposes in regional studies. In the study of Chinese agricultural production, the homogeneous and planning regions have been used the most, though there are differences in choosing the key criteria and in understanding the regional identities in different studies. Changes in policy makers' national strategies have also affected the definition of planned regions.

3.2.2 Agricultural Division - Homogeneous Regions

Agricultural production is conducted in an open ecosystem. The diversities of this ecosystem, together with the different socio-economic factors, generate great variations in agricultural production in different areas. However, prior to the 1970s, except for a few western scholars, such as Buck (1937, 1968)[1], studies of regional agricultural and grain production in China were rather rare.

The systematic study of China's agricultural divisions commenced in the 1970s, when agricultural scientists and geographers worked together to divide China into several agricultural regions. The most recent and the most sophisticated division was the comprehensive agricultural division completed by the Committee of National Agricultural Division in the 1980s. Map 3.1 shows the spatial distribution of the regions.

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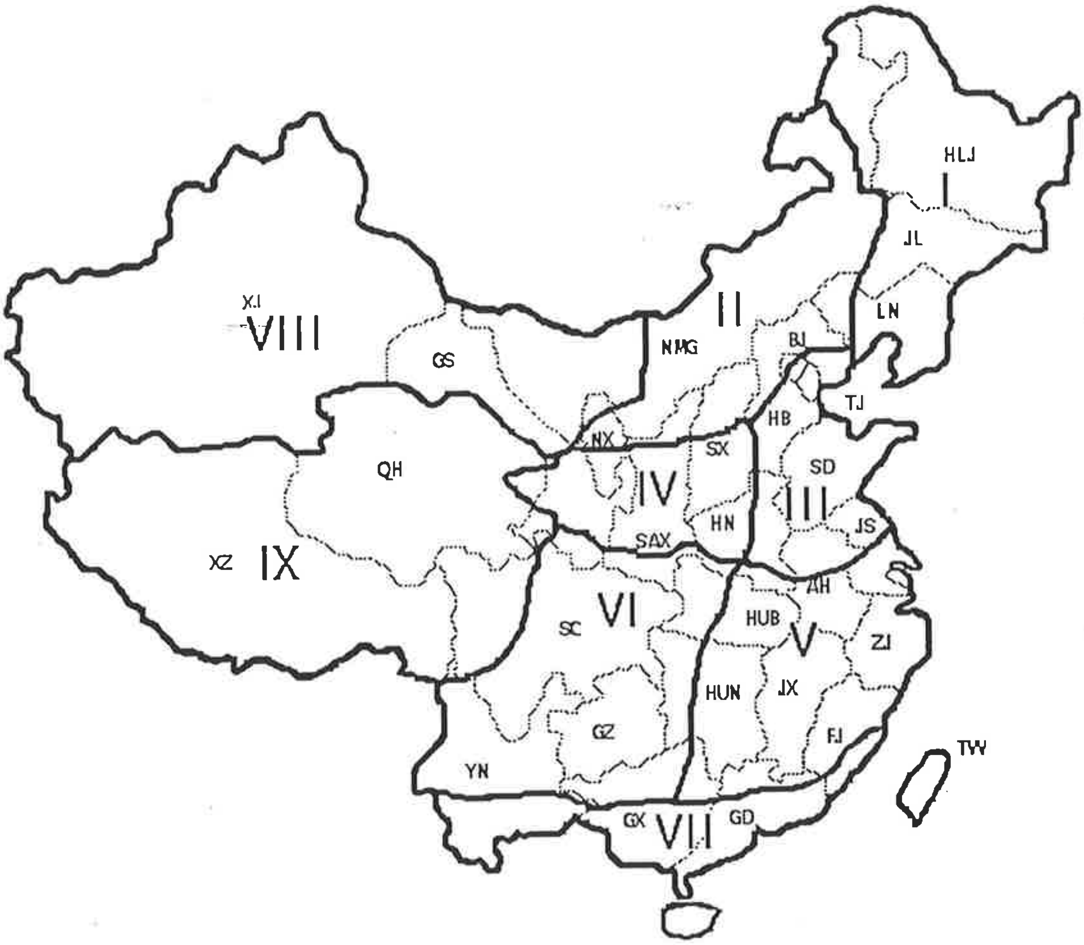
[1] Buck's survey divided China into eight agricultural areas: spring wheat, winter wheat and millet, winter wheat and sorghum, Sichuan rice, Yangzi rice, rice and tea, southwest rice and double rice.

Map 3.1 China's Agricultural Regions



I. Northeast; II. Inner-Mongolia and North of the Great Wall; III. The Huang-Huai-Hai; IV. The Loess Plateau; V. The Middle and Lower Yangzi River; VI. Southwest; VII. South; VIII. Gan-Xin; IX. The Qing-Zang Plateau

Source: Committee of National Agricultural Division of China 1987. p.333.

This division is based on four homogeneous principles: 1) relative homogeneity in terms of natural and socio-economic conditions; 2) relative homogeneity in the basic characteristics of agricultural production and direction of further development; 3) relative homogeneity in respect of problems in agricultural production and in the direction of development; and 4) a consistency with county administrative boundaries. According to these principles, nine agricultural regions have been defined. The basic characteristics of each region with respect to grain production are summarised below (the numbers are those in the map).

I. In the Northeast region, the history of agriculture is relatively short. The average land/person ratio is relatively high. The major food grain crops of this region are corn, spring wheat and soybean.

II. Inner-Mongolia and North of the Great Wall is a region where the climate varies from semi-humid to semi-arid. Grassland dominates the natural landscape. Animal husbandry is the major activity in this region. Grain production is less important. The major grain crops in this region are spring wheat, corn, and some coarse crops

III. The Huang-Huai-Hai region is given its name by the three flood plains. It has a long history of cultivation and population density is high. This region is the major producing area for winter wheat, corn, cotton, and oilseeds. The grain production of this area occupies an important position in national production.

IV. The Loess Plateau region is characterised by numerous gullies. Soil erosion is a major problem. Due to the erosion and high variance of rainfall, agricultural production is unstable and yields are low. Wheat and coarse crops are predominant in this region.

V. The Middle and Lower Yangzi River region possesses a sub-tropical climate. Topography is characterised by alternating flat plains and low hills. Temperature, water and soil conditions are generally favourable for agricultural production. Rice production is the dominant crop in the region, and it is important in terms of national grain production.

VI. The Southwest region is also located in a sub-tropical area. The topography is dominated by hills and mountains. This results in a vertical disparity of natural conditions and hence a disparity of agricultural production. Rice is the major grain crop in this region, although wheat and corn are also widely planted.

VII. The Southern region possesses a climate that ranges from sub-tropical to tropical. Multiple cropping is common in this region. It is the only area where tropical cash crops can be produced. Rice is the major grain crop in this area.

VIII. The Gan-Xin region is inland. Large day-night temperature differentials and an arid climate are the basic characteristic of this region. Water is essential for agricultural production. Spring wheat is the major grain crop in this area.

IX. The Qing-Zang plateau region is dominated by mountain ranges. Low temperatures and a lack of rainfall all year round restrict agricultural production. Extensive animal husbandry is the major activity. Spring wheat and some coarse crops are the major grain crops in this area.

These divisions into agricultural regions reflect the basic characteristics of each region in relation to grain production. They also indicate the direction of further development in agricultural production. Accordingly, it would be appropriate to apply these divisions in comprehensive studies of regional grain production. In practice, however, some difficulties constrain their usage. One of the major problems is that the boundaries between regions are consistent with the county boundaries, whereas in Chinese statistics most data are collected at either the national or the provincial level. County level data tend to be extremely rare. In addition, taking into consideration that there are approximately 2367 county-level units in China (SSB, 1991, p.3),[2] such data processing would be an onerous task even if the data at the county level were available. For this reason, these divisions are rarely used in studies of regional agricultural production. Nevertheless, the homogeneous principles of these divisions have been applied to many regional studies which will be referred to in the next section.

3.2.3 Agricultural Regions with Provincial Administrative Boundaries

In studies of Chinese agricultural production, the most commonly used method of defining a region is to combine the agricultural regions with provincial administrative boundaries. That is to group several provinces which are relatively homogeneous in terms of geographical features and/or economic conditions into one region.

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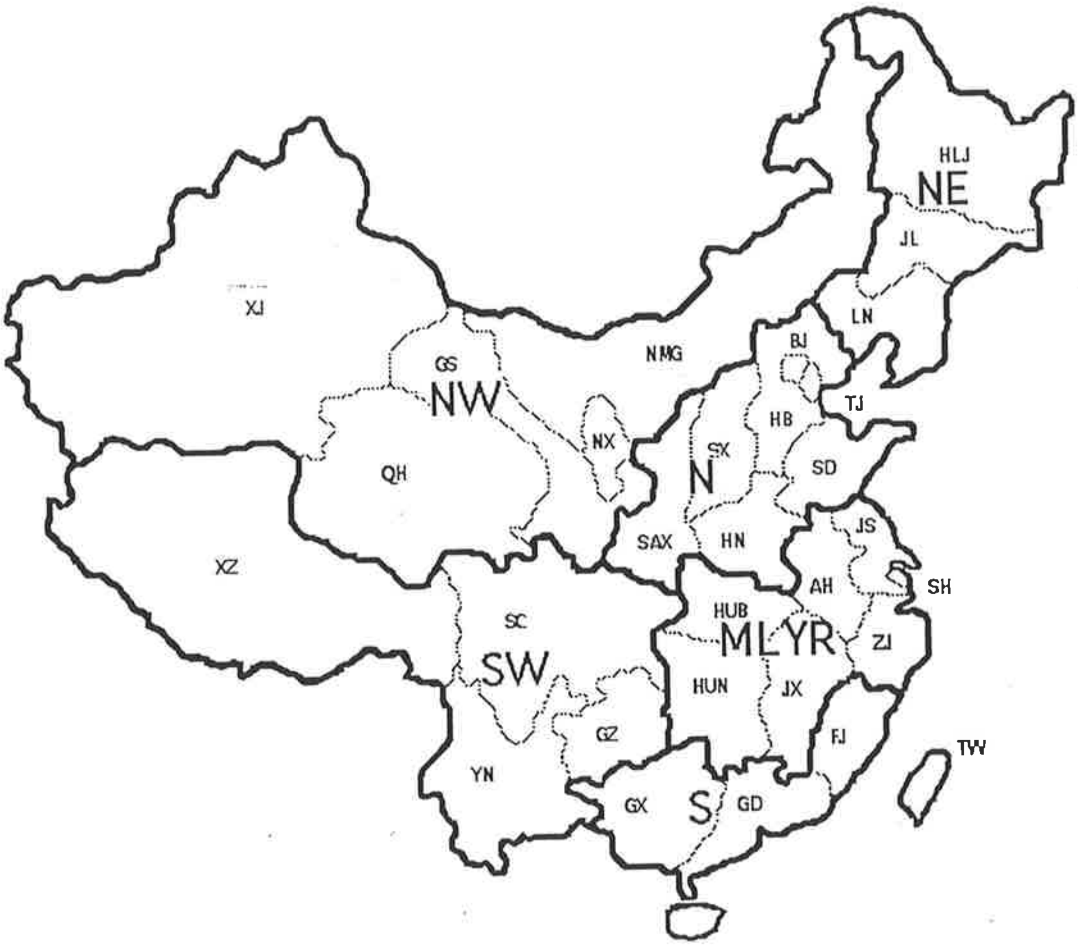
2 The figure for the number of counties changes from time to time due to changes in administrative bundaries.

Map 3.2 Agricultural Regions Based on Provincial Boundaries



NE. Northeast; N. North; NW. Northwest; MLYR. Middle and Lower Reach of the Yangzi River; S. South; SW. Southwest.

Source: Chinese Academy of Agricultural Sciences (Group for the Study of Mid and Long-term Food Development Strategies), 1991.

Map 3.2 demonstrates the regions used in the study of mid and long-term food development strategies, conducted by the Chinese Academy of Agricultural Sciences (1991), in collaboration with several other research institutes between 1988 and 1990. There are six regions. By comparing this with Map 3.1, it can be observed that the Inner-Mongolia and north of the Great Wall, Gan-Xin, and Qing-Zang regions are combined into a single western region. The Huang-Huai-Hai region and the Loess Plateau region are merged into one named North. The characteristics of the remaining regions are relatively similar in the two divisions, except that in the division of the Chinese Academy of Agricultural Sciences shown in Map 3.2, the regional boundaries are consistent with the provincial boundaries, which makes the regional analysis practically feasible.

Apart from the above definitions, there are a number of other definitions of regions that have been used in previous studies. To get a clearer view of the similarities and disparities of these definitions, Table 3.1 lists some of the regional definitions and specifies the components in each region.

In the various divisions listed above, apart from the Seventh Five-Year Plan, the three north-east provinces have been grouped into one region. This reflects their relatively homogenous features in terms of both natural conditions and economic development. In addition, the provinces included in the Northwest (Pastoral in Carter and Zhong) and Southwest regions are also similar in different divisions. However, the definitions and provinces included in other regions differ significantly. This is partly caused by a different emphasis in the definitions. For example, Fan's definition is concerned with the homogeneity of geographical features. Carter and Zhong's definition emphasises the homogeneity of major crops in each region. By contrast, the definition of the State Statistical Bureau is based on

Table 3.1 Several Definitions of Regions in Studies of Agricultural Production[a]

CAAS[b] (1991)	Fan (1990)	Carter & Zhong (1988)	SSB (*ZTN*)	SFYP[c] (*ZNTN*)
Northeast	**Northeast**	**Spring Wheat**	**Northeast**	**Coastal**
Liaoning	Liaoning	Liaoning	Liaoning	Liaoning
Jilin	Jilin	Jilin	Jilin	Beijing
Heilongjiang	Heilongjiang	Heilongniang	Heilongjiang	Tianjin
				Hebei
North	**North**	**Winter Wheat**	**North**	Shandong
Beijing	Beijing	Beijing	Beijing	Shanghai
Tianjin	Tianjin	Tianjin	Tianjin	Jiangsu
Hebei	Hebei	Hebei	Hebei	Zhejiang
Henan	Henan	Henan	Shanxi	Fujian
Shandong	Shandong	Shandong	Neimenggu	Guangdong
Shanxi	Shanxi	Shanxi		Guangxi
Shaanxi	Shaanxi	Shaanxi		
	Gansu			
Northwest	**Northwest**	**Pastoral**	**Northwest**	**Central**
Neimenggu	Neimenggu	Neimenggu	Shaanxi	Heilongjiang
Ningxia	Ningxia	Ningxia	Gansu	Jilin
Xinjiang	Xinjiang	Xinjiang	Qinghai	Shanxi
Qinghai	Qinghai	Qinghai	Ningxia	Neimenggu
Gansu	Xizang	Gansu	Xinjiang	Henan
		Xizang		Hubei
				Anhui
MLYR[d]	**Central**	**Wheat-Rice**	**Central & South**	Hunan
Hunan	Jiangxi	Anhui		Jiangxi
Hubei	Hubei	Jiangsu	Henan	
Jiangxi	Hunan	Hubei	Hubei	
Shanghai			Hunan	
Jiangsu			Guangdong	**West**
Zhejiang			Guangxi	Xinjiang
Anhui				Gansu
	Southeast	**Double Rice**	**East**	Qinghai
	Shanghai	Shanghai	Shanghai	Shaanxi
	Jiangsu	Jiangxi	Jiangsu	Ningxia
	Zhejiang	Zhejiang	Zhejiang	Sichuan
	Anhui	Hunan	AnhuiXizang	Guizhou
		Guangdong	Fujian	Yunnan
South	**South**	Guangxi	Jiangxi	
Fujian	Fujian	Fujian	Shandong	
Guangdong	Guangdong			
Guangxi	Guangxi			
Southwest	**Southwest**	**Southwest Rice**	**Southwest**	
Sichuan	Sichuan	Sichuan	Sichuan	
Guizhou	Guizhou	Guizhou	Guizhou	
Yunnan	Yunnan	Yunnan	Yunnan	
Xizang				

a. Hainan is integrated into Guangdong province for reasons of data consistency.
b. Regions used by the Chinese Academy of Agricultural Sciences (1991) in "The Study of Mid and Long-term Food Development Strategy".

c. Regions defined in the Seventh Five-Year Plan (SSB, *ZNTN*).
d. Middle and Lower Reach of the Yangzi River.

administrative regions. These differences, however, are also the result of a different understanding among scholars of the concept of agricultural regions. It can be seen that the provinces in the inconsistently defined regions are all important in Chinese national grain production. This inconsistency thus certainly affects the results of regional studies, creating some difficulties in understanding characteristics of Chinese regional agricultural production.

The division into three economic regions, i.e., the coastal region (or the eastern region), the central region and the western region is also used by some scholars.[3] This definition was initially raised in the Seventh Five-Year Plan on the basis of the levels of economic and technological development of each region. This approach is typical of planning regions. The coastal region is the most developed area. The central region is the transition area between the developed coastal region and the less developed western region. The western region represents the interior, and its economy lags far behind that of the eastern region. This division reflects, to a certain extent, the economic and technological conditions for agricultural development in different regions. It is, however, rather general and does not take into account the effect of natural conditions and the structure of agricultural production.

In examining whether or not the above regional definitions are appropriate to study Chinese grain production, it is necessary to examine whether or not these definitions have maximised the inter-regional disparities and minimised the intra-regional differences. In other words, given the

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3 This definition is quoted by many studies, such as Liu Zhicheng, ed (1989), Li Qingzeng, et al (1991).

criteria, it is necessary to know whether or not there is a significant homogeneity within a region and a heterogeneity between regions.

Analysis of the regional definitions in Table 3.1 gives an impression that the homogeneity within a region is weak and the heterogeneity between the regions is not strong. For example, in Fan's definition, Gansu is classified into the North region. However, empirical evidence shows that Gansu's agricultural production is more similar to that of Qinghai or Neimenggu than to that of Shandong, which also belongs to the North region. In Carter and Zhong's definition, Jiangsu and Shanghai belong to two different regions though Shanghai is in fact surrounded geographically by Jiangsu and there are great similarities in these two areas. In addition, Carter and Zhong defined, Heilongjiang, Jilin and Liaoning as part of the Spring Wheat region. However, in the latter two provinces, the sown area of spring wheat only accounts for 2.3 percent and 0.7 percent of their total grain sown areas, respectively (Carter and Zhong, 1988, p.65). The name of the region therefore does not reflect the characteristics of regional grain production. The definition used by the State Statistical Bureau is an administrative definition. It does not fit a common criterion for agricultural production. Therefore, using this definition in regional agricultural analysis becomes even more problematic.

The regional identity in terms of agriculture is extremely weak in the definition of the Seventh Five-Year Plan. For example, Guangdong and Hebei belong to the coastal region, yet their natural conditions for agricultural production are significantly different in respect of temperature, rainfall, soil types, etc. During the reform period, the development of their rural economies has taken place at different paces: Guangdong has had much faster growth than Hebei. These differences have not only resulted in great variations in the dominant crops and the farming systems adopted, but also in the levels of technology and productivity, as well as in the potential for grain production. In short, the above-mentioned differences between these two provinces have made their common feature of being in the coastal area, of little significance for agricultural production. A similar problem can be seen in the regional division of Sichuan and Xizang. Both belong to the western region. However, the economic status and agricultural conditions in Sichuan are much more advanced in comparison with Xizang. The concept of the "three regions" cannot distinguish common characteristics for studying regional agricultural production.

3.2.4 Provinces and Regions

Despite the different regional definitions, there is a noteworthy common feature among most divisions; that is, the boundaries of the regions are consistent with the provincial boundaries, each region consisting of several provinces. As such, provincial boundaries are an important criterion in dividing regions.

At this point, it should be emphasised that decentralisation has been a trend evident during the reform period. The central planning system has been gradually weakened, and provincial governments have been handed increasing power to administer provincial production. As a result, similarities within regions defined above have been further reduced, whereas dissimilarities have become increasingly apparent. This trend makes the effort of grouping several provinces into one region neither necessary nor appropriate.

In recent years, the study of provincial agricultural production has been increasing.[4] One of the reasons is that individual provinces have become increasingly independent in planning the local economy. By the end of the 1980s, all provinces, except for Xizang, had their own plan for agricultural development. By contrast, there are few inter-provincial joint plans involving the development of agricultural production. The conventional regional concept, which puts several provinces into one region, therefore, has little significance. For all the above reasons, this study simply treats all the individual provinces as regions. This, on the one hand, avoids the complex and sometimes arbitrary definition of regions; on the other hand, it is a more convenient way of observing the role of provincial governments in local agricultural production.

While acknowledging the advantages of such a provincial approach in regional studies, it is also apparent that this approach is more cumbersome considering that all provinces have to be considered separately. Nevertheless, the provincial-based regions best reflect the disparities among different regions. The provincial approach is the most appropriate option, at least until more complete data at the county level become available.

Under China's administrative system, autonomous regions and municipalities are equivalent to provinces, and in this study they are treated as provinces for convenience. There are, however, some exceptions to this approach. Although Hainan became a separate province in 1988, in this study it is integrated into Guangdong for the sake of data consistency. In addition, because of a lack of statistical data for Xizang and its minor position in

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[4] For example: Feng Haifa, 1987; Tian Weiming, 1987; Wan Guanghua, 1992; Lardy, 1990; and Liu Zemeng, 1992.

national grain production, it is excluded in most of the following analysis. There are therefore 28 provinces covered by this study.

In this study, some directional terms indicating the location of provinces will be used. For example, the eastern provinces refer to the provinces in the eastern part of China. Similarly, southern provinces refer to the provinces to the south of China. These are meant as purely directional concepts rather than denoting specific regions.

3.3 Some Conceptual Issues

Since the rural reforms began, there has been a spectacular development in the two dominant sectors: agriculture and rural enterprises. However, the definitions of these two sectors are also the most confusing ones in terms of a systematic study of Chinese rural economy. This section aims to clarify these two concepts.

3.3.1 Agriculture: "Big" and "Small"

Agriculture is a large and multi-sectored system. Grain production is one of the important components in this system. There are interactions among the different sectors within agricultural production, and grain production is often influenced by other sectors. Therefore, when studying grain production, it is inevitable that one needs to consider the situation of agricultural production as a whole. However, in China, the definition of "agriculture" is complex and the sectors contained also vary.

For historical and political reasons, the term "agriculture" is not a precise concept. Prior to the 1970s, the term "agriculture" referred to all rural activities, including crop farming, forestry, animal husbandry, fishery and sidelines (including industry owned by collectives). Of these activities, crop farming was the dominant sector. Grain and cotton were particularly emphasised. Other activities, especially rural industries, were restricted for most of the time during this period. As a result, the non-crop farming sectors developed fairly slowly and only accounted for a small proportion of the rural economy. For example, in 1971, the gross output value of crops accounted for 75.1 percent of total gross output value of all agricultural produce. Of the other 24.9 percent rural industries accounted for 3.6 percent (SSB, *ZTN*, 1983, p.151). For this reason, before the 1980s, the term "agriculture" mainly referred to crop farming, and it did not seem to cause much confusion.

Beginning in the late 1970s, and continuing during the 1980s, economic reforms brought about remarkable changes in various aspects of the rural economy. One of the most dramatic changes was the rapid development of non-crop farming sectors, in particular, rural industries. By 1983, the non-crop farming sector accounted for 38.1 percent of the total gross value of agriculture (ECCAY, *ZNN*, 1984, p.136). Of this, rural industries accounted for 13 percent, compared with 3.6 percent in 1971. The old definition of agriculture became more and more inappropriate in reflecting the characteristics of the rural economy. The rapid expansion of non-crop farming sectors ushered in a profound change in the foundation of the rural economy.

From 1984, the gross output value of agricultural production no longer included the gross output value of rural industry. This was one step towards clarifying what "agriculture" meant in the Chinese context. However, the remaining sectors, including crop farming, animal husbandry, forestry, fishery and sidelines still make the domain of agriculture fairly general, wideranging and complex. Since the rural economic reforms began, these sectors have become increasingly differentiated from what once was understood as traditional agriculture. For this reason, in recent years many scholars have tended to separate the general term "agriculture" into individual sectors and to use agriculture to refer the crop farming sector only. To distinguish this concept from the old or broad term, the crop farming sector has become known as "small agriculture" whereas, the old concept of agriculture has become known as "big agriculture".

In the present study, the term agriculture refers to the narrow sense, i.e., the crop farming sector only. This is because the crop farming sector exhibits relatively similar characteristics in the way resources are used and in the procedure by which production is managed.

3.3.2 Rural Enterprises and Rural Industries

Another issue which needs to be clarified is the concept of rural enterprises and their relationship with rural industries. Rural economic reforms have brought about remarkable changes in rural areas. One of the most significant features has been the rapid development of rural enterprises, in particular, rural industries. Many studies have pointed out that the rapid development of rural enterprises has affected grain production through its effect on resource transfer, including the transfer of land, labour and capital (Chen Jiyuan and Geng Dechang, 1990; Lei Qiquan, 1990, et al ; Zhu Xigang, 1991). However, in practice, different definitions of rural enterprises have been used in both statistics and empirical studies. It is therefore necessary to clarify the different definitions and to define the concept and scope of rural enterprises in the present study.

As mentioned earlier, since the reforms began, rural non-crop farming sectors have developed rapidly. This development has had a strong impact upon the rural economy. Various types of enterprises were established in rural areas and the ownership of these enterprises range from townships, villages, and cooperatives to private individuals. Depending on the characteristics of the products, these enterprises are classified into industrial enterprises, agricultural enterprises, transportation enterprises, commercial enterprises and so forth.

In Chinese official statistics, the scope of such enterprises is not consistent. Before 1984, the figures for rural enterprises included only township and village owned (*xiangban he cunban*) enterprises. The enterprises owned by cooperatives (*lianban)* and individuals (*geti*) were not taken into account. However, with the rapid development of cooperative and individual enterprises, the exclusion of these two items from rural enterprises became increasingly inappropriate. For example, in 1985, the gross output value of enterprises owned by cooperatives and individuals accounted for 33.12 percent of the sector's total gross output value (ECCREY, *ZXQN*, 1989, p.77). This figure tended to increase in later years. Beginning in 1985, two kinds of rural enterprises have been used in official statistics. One is "*xiangzhen qiye*", which refers to all enterprises owned by townships, villages, cooperatives and individuals. Another concept is "*xiangcun qiye*", which includes the enterprises owned by townships and villages only. The latter concept is consistent with the scope of rural enterprises before 1984.

It is clear that the term "*xiangzhen qiye*" is broader than the term "*xiangcun qiye*". In examining the aggregate effect of rural enterprises on grain production in this study, the term "rural enterprises" refers to "*xiangzhen qiye*", which includes all township, village, cooperative and individual enterprises.

Although the term "rural enterprises" includes various enterprises in rural areas, those involving industry account for the largest proportion. For example, in 1985, the gross output value of industrial enterprises accounted for 67 percent of the total gross output value of rural enterprises (ECCREY, *ZXQN*, 1989, p.74), and in 1990, it grew to 71.5 percent (SSB, *ZTN*, 1991, p.378). Rural industries have dominated the overall make-up of rural enterprises. In considering the effect of rural enterprises on grain production, the status of the rural industry sector should receive particular attention.

In contrast with industrial enterprises, the gross output value of agricultural enterprises only accounts for a very small proportion. In 1990, the share of the agricultural enterprises in total gross output value was 1.67 percent (SSB, *ZTN*, 1991, p.378). According to the definition in official statistics, agricultural enterprises refers to collectively-owned orchards, piggery and poultry factories, and fish ponds (Li Chengrui, (ed), 1986). With the continuing transfer of the ownership of these activities from collectives to individual households, the proportion of the gross output value of agricultural enterprises in total rural enterprises has been declining. Because of the small and shrinking proportion of agricultural enterprises, their role in overall rural enterprises has become negligible.

3.4 Underreported Figures for Cultivated Land and Their Possible Impact on the Analysis of the Present Study

Data inaccuracy has often been a problem in studies of Chinese agricultural production. One of the most common problems is the underestimation of the amount of cultivated land area. In officially published statistics, China's cultivated land is 1.44 billion mu (96.3 million hectares), although it is acknowledged that the actual figure for cultivated land area should be larger than the one shown in the statistics (SSB, *ZTN*, 1991). The actual figure for cultivated land in China is thus still a mystery. According to a recent survey by the Committee of National Agricultural Division (Zoning) of China, the actual cultivated land in China could be about 30 percent higher than the officially reported figure (Committee of National Agricultural Division of China, 1987). According to a 1985 survey, there was an estimated 44 percent more cultivated land than that reported by the State Statistical Bureau. Estimated underreporting varies from a low of 14 percent in Hebei Province to a high of 162 percent in Guizhou Province. Provinces in poorer mountainous areas tend to underreport more cultivated area than provinces in the richer and more fertile plains (Crook, 1993).

Underreporting of cultivated land area may have been the result of a number of factors. First, there exist incentives for collectives and individual households to underreport their land. If less land is reported, then fewer taxes need to be paid. There may also be some political reasons. In many areas, yield has [illegible] often been regarded as a criterion to evaluate local cadres' work. To gain political kudos, local cadres tended to report less cultivated land so that the yield would be higher, given the amount of total output (Bai Fuyi, 1994).

Secondly, the underreporting of cultivated land area is also due to the fact that different areas in China have used different units to measure land surface area. According to a source in one province, farmers in an area of intensely cultivated plains used 667 square meters to report 1 mu of cultivated area while farmers in hilly and mountainous areas used 900 square meters to report 1 mu (Crook, 1991a). An interview by the author with the Director of the Department of Agricultural Policy and Law of China also supports this point.[5] The Director, Mr Luo Yousheng, argues that different measurements used in local areas are the main causes of the underreporting of cultivated land. Locally used measurement units are generally larger than the standard unit. In addition, the author's own experience in Qinghai province shows that even in one area, the measurement could also be affected by the different qualities of land. The production team the author worked with between 1975 and 1976, allowed different measurements for different land quality. Land located in the valley areas was of relatively good quality and the area of this land was measured accurately, i.e, 667 square meters. Land on the hills was generally poor and was often measured roughly. One mu was generally bigger than the standard measure. The implication of the non-standard measurement in different areas and for different land quality is that the actual figure for China's cultivated land area can never be arrived at from the locally reported figures. However, as most of the underreported land is poor land, the effect of underreporting on the estimation of grain output is limited to some extent.

Given that the cultivated land area is underreported, an immediate question that needs to be raised is: what is the effect of underreporting on the analysis in this study? The answer is that it is fairly limited. Most of the analyses in this study, especially those of productivity, are based on empirical household survey data collected in recent years by a number of official agents. In such sources, the measurement of land unit is broadly consistent and standard (667 square meters per mu) for different regions. This, on the one hand, has the effect of limiting the gap between actual figures and reported figures in land input and yield; on the other hand, it makes it possible to compare input levels and yields among different regions. The use

[5] The interview was made during Luo Yousheng's visit to Adelaide in November, 1993.

of the household survey data in this study also helps overcome some of the data problems by providing direct measures of actual land inputs.

It is worth pointing out that although underreporting of cultivated land is a fact, the effort that individual farmers put into their contracted land is not affected by this matter. When cultivated land was assigned to individual households in the early 1980s, there was no distinction between reported land and "black land". Farmers were assigned responsibility and obligations according to the amount of their contracted land. This would have further limited the effect of underreported land area on the analysis of changes in total factor productivity of grain production at the household level.

However, this study cannot avoid using the national statistics. Due to the underreporting of cultivated land, the real grain sown area is systematically higher than that officially recorded. Nevertheless, as Yu Chenliang and Buckwell (1991, p.72) have pointed out, such a systematic downward bias would be consistent for the whole historical development period. It may therefore be argued that the underreporting of cultivated land has a limited effect on historical studies of changes in total factor productivity of grain production.

Chapter 4

An Overview of China's Grain Production, 1978-1990

4.1 Introduction

Since the agricultural reforms began at the end of the 1970s, China's overall grain production has experienced significant changes in sown area, yield, and output, as well as in structure of grain types. These changes distinguish the development of grain production in the reform era from the preceding 1952-1978 period.

The changes in grain production, however, have been uneven, with the growth varying by time, place and crop. This chapter examines the changes in grain production at both the national and provincial levels. Historical changes in grain production are referred to for the purpose of comparison. On the basis of this overview, some implications for the changes in total factor productivity and provincial disparities in grain production since 1978 will be considered.

The chapter is organised as follows: Section 2 examines the major differences between the reform period and the preceding years in terms of the changes in grain production, highlighting the significance of the reform period. Section 3 focuses on grain production at the national level. It investigates the uneven development among the respective grain crops between 1978-1990. Section 4 gives an insight into the details of the changes in different provinces for respective grain crops. A summary of the findings and their implications for changes in total factor productivity forms the concluding section.

4.2 The Long-term Trends in China's Grain Production

From the mid 1960s, China's grain production has experienced an increase in output with an accompanying decline in sown area. This feature is no doubt associated with China's predicament - an ever growing population and a limitation on available arable land. Since 1978, this feature has been more pronounced, with an accelerated increase in grain output and a rapid diminution of sown area.

Table 4.1 shows the significant difference between the two periods. Generally speaking, after 1978, grain output increased more rapidly compared with the previous period. Between 1952 and 1978, grain output increased by 140.85 million tonnes, averaging 5.42 million tonnes annually. Between 1978 and 1990, however, the total increase in grain output was 141.47 million tonnes, more than the total increase in the previous 26 years. The average annual increase in grain output was twice that of the previous period.

Grain sown area changed in a different manner to that of the output. Between 1952 and 1978, total grain sown area decreased by 50.87 million mu, averaging 1.96 million mu annually. Between 1978 and 1990, total grain sown area decreased by 104.83 million mu, averaging 8.90 million mu. This rapid diminution in grain sown area has been a marked feature of the reform period.

Table 4.1 Grain Output, Sown Area and Yield, 1952, 1978 and 1990

	Total			Increase	
	1952	1978	1990	1952-78	1978-90
Output (mmt)	163.92	304.77	446.24	140.85 (5.42)*	141.47 (11.79)
Sown area (mmu)	1859.68	1808.81	1703.98	-50.87 (-1.96)	-104.83 (-8.90)
Yield (kg/mu)	88	168.50	262	80.50 (3.10)	93.50 (7.79)

* Figures in brackets are the average annual increase.

Source: Data for 1952 and 1978 are from SSB, *ZTN*, 1983, p.154, p.158, p.171. Data for 1990 are from SSB, *ZNTN*, 1991, p.87, p.101, p.113.

Because of the scarcity of arable land, intensive farming has long been typical of Chinese agricultural production. Increasing yields is an important means for increasing overall grain output. Since the founding of the People's Republic, the increase in grain yield has been almost the sole contributor to the increase in total output. This feature has become even more apparent during the reform period. Table 4.1 shows that between 1952 and 1978, grain yield increased by 80.50 kg/mu, an annual increase of 3.10 kg/mu. Between 1978 and 1990, grain yield increased by 93.50 kg/mu, averaging 7.79 kg/mu annually, indicating a remarkable increase in land productivity. This suggests that increasing grain output in China has become more and more reliant on the increase in yields. It underlines the importance of examining the details of the changes in land productivity or yield. This task will be undertaken in Chapter 5.

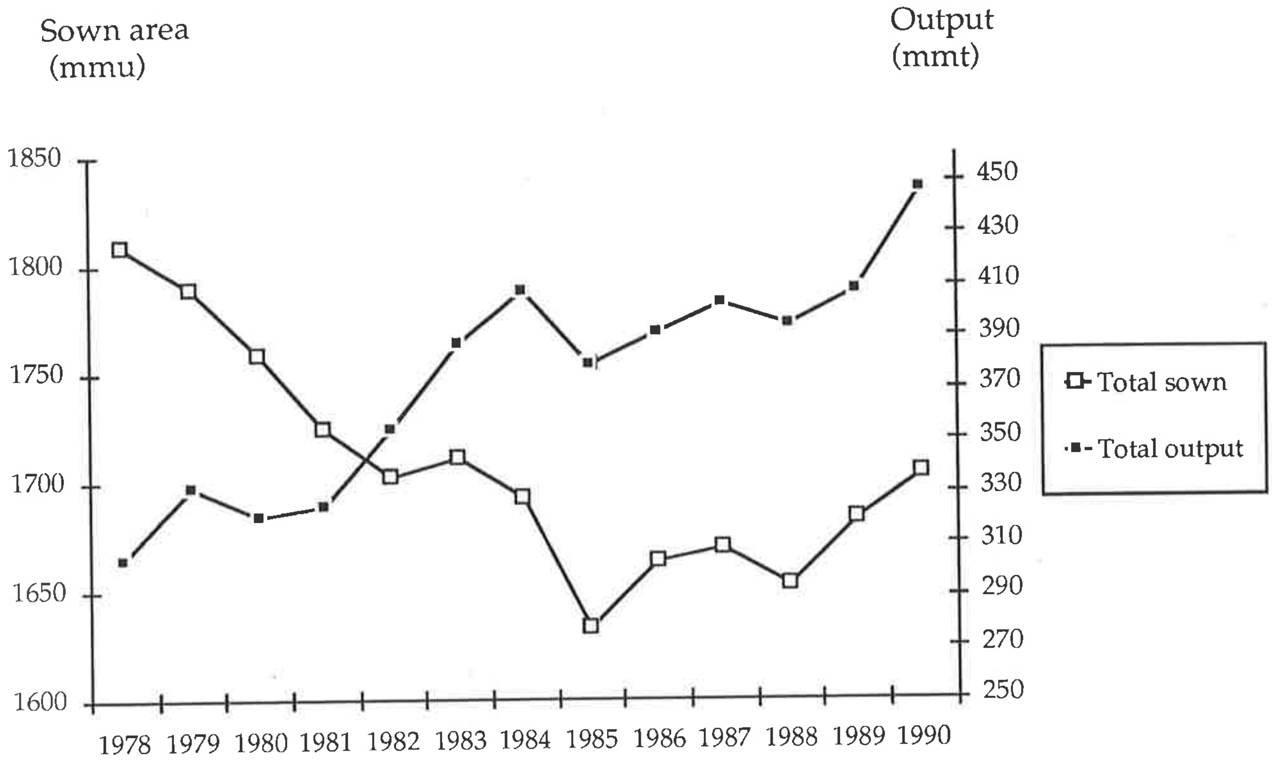
4.3 National Grain Production and Structural Change Between 1978 and 1990

During the reform period, grain output experienced a rapid growth whereas sown area decreased significantly. These changes, however, were uneven over time and significant variations existed among different grain crops. In this section, the focus is on specifying changes in national grain production between 1978 and 1990.

4.3.1 Changes in National Grain Production

The trends in changes in grain output and sown areas between 1978-1990 are demonstrated in Figure 4.1. The two lines representing grain output and sown areas form an "X", illustrating the opposing trends. Despite this, two sub-periods separated by the drastic drop of grain output in 1985 can be identified. The first of these is between 1978 and 1984, the second from 1985 to 1990. During these two periods, grain output started from a low level and then increased in the following years. The comparison between the two sub-periods shows that the first sub-period experienced a more rapid growth in grain output. In the second sub-period, the growth of grain output was only modest. As for the grain sown area, the drastic decrease occurred in the early years of the reforms, dropping to its lowest level in 1985. After that year, the grain sown area recovered slightly, though in 1990 it was still less than at the beginning of the reforms.

Figure 4.1 Changes in Grain Sown Area and Output, 1978-1990



Source: SSB, *ZTN*, 1991, p.340 and 346.

It should be pointed out that there has always been a positive relationship between grain output and sown area in China. Many previous studies have supported a high elasticity with respect to land input in China's agricultural production, despite the variations in the actual values of the elasticity among the authors (see Chapter 2). The opposing trend in the early years of the reform, therefore, is outside normal expectations. Many scholars have attributed the rapid growth in output to an improvement of total factor productivity, initiated from the rural economic reforms, in particular the implementation of the HRS (Zheng Zhong, 1988; McMillan, et al, 1989; Cai Fang, 1990; Fan Shenggen, 1990; Lin Yifu, 1992; Zhang Bin and Colin Carter, 1993). In Chapter 7 and Chapter 8 of this study, the analysis of the sources of growth supports this opinion.

As can be seen in Figure 4.1, the trend of grain output after 1985, matched the trend of grain sown areas. This indicates that sown area continues to play a crucial role in determining grain output. This relationship helps to explain why stabilising grain sown areas has been strongly re-emphasised after 1985, principally to ensure grain supply.[1]

The uneven changes in grain output and sown areas can also be observed in individual grain crops. Table 4.2 and Figure 4.2 show that the output of wheat, rice, corn and miscellaneous grain crops all increased significantly between 1978 and 1984 and decreased suddenly in 1985. After 1985, there was a modest increase for all grain crops except for miscellaneous crops. The pace of the growth, however, varied among respective grain crops. Figure 4.2 shows that during the early years of the reforms, output of rice and wheat increased faster than corn. After 1985, the trend was reversed. For miscellaneous crops, the increase was much slower than those three major grain crops during the first sub-period, and remained fairly stable after 1985. The variations in growth patterns among different grain crops were related to many factors. These will be explored step by step in the rest of this thesis.

Overlapping the general trend of the two sub-periods, fluctuations in output were significant in individual years. Figure 4.2 shows that of all the grain crops, fluctuations in the output of wheat were relatively minor compared with other grain crops, corn in particular. This feature may imply that wheat production has been relatively less affected by the factors that have been responsible for the fluctuations in other crops. In contrast, corn

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1 According to the suggestion of the State Statistical Bureau, grain sown areas should be stabilised around 1680 million mu (SSB, Survey Team of Production Costs of Crops, 1992). This may explain the panic over grain supply in 1985, when the sown areas were significantly below this level. A result of this was the administrative intervention, which made the recovery of grain sown areas in the later years inevitable.

production has been more sensitive to the changes in external factors. This hypothesis will be tested in the later chapters of this study.

Table 4.2 Changes in Grain Outputs, 1978-1990

(million tonnes)

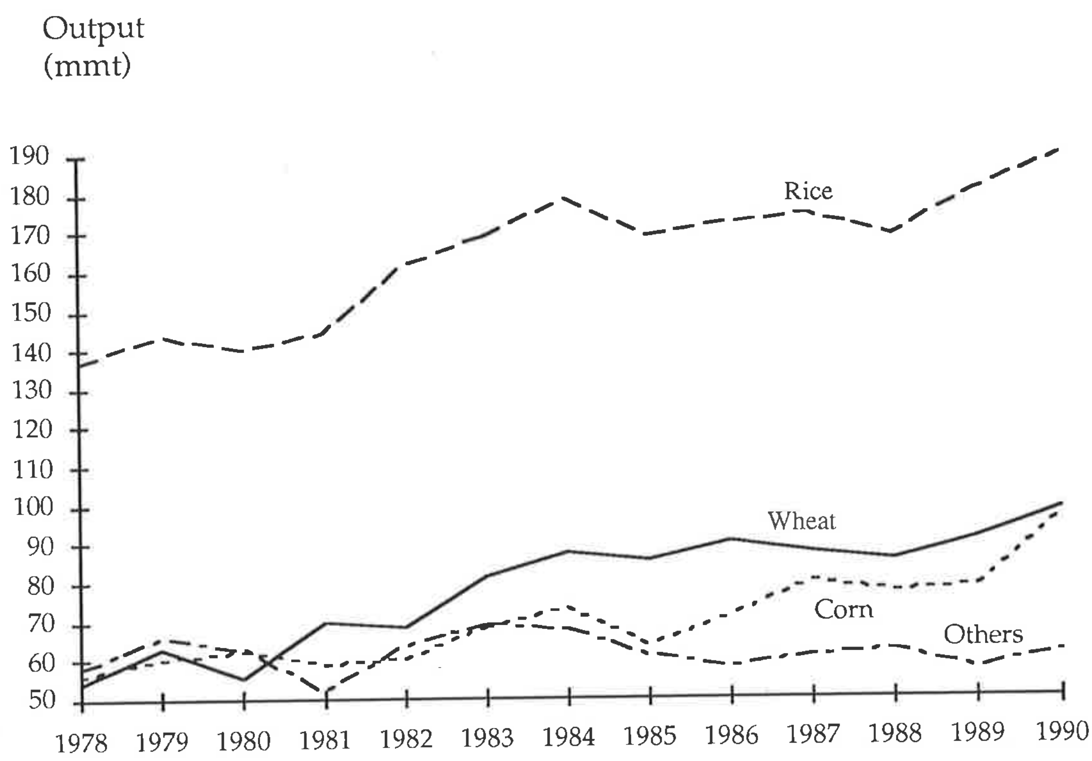
Year	Total	Wheat	Rice	Corn	Miscellaneous
1978	304.77	53.84	136.93	55.95	58.05
1979	332.12	62.73	143.75	60.04	65.60
1980	320.56	55.21	139.91	62.60	62.84
1981	325.02	69.64	143.96	59.21	52.21
1982	354.50	68.47	161.61	60.56	63.86
1983	387.28	81.39	168.87	68.21	68.81
1984	407.31	87.82	178.26	73.41	67.82
1985	379.11	85.81	168.57	63.88	60.85
1986	391.51	90.04	172.22	70.86	58.39
1987	402.98	87.77	174.42	79.82	60.97
1988	394.08	85.43	169.11	77.35	62.19
1989	407.55	90.81	180.13	78.93	57.68
1990	446.24	98.23	189.33	96.82	61.86
Change*					
1978-84	102.54	33.98	41.33	17.46	9.77
1985-90	67.13	12.42	20.76	32.94	1.01
1978-1990	141.47 (46.42)**	44.39 (82.45)	52.40 (38.27)	40.87 (73.05)	3.81 (6.56)

* The sum of the change during the two sub-periods is inconsistent with the change over the whole period. This is due to the fact that the two sub-periods' figures do not take into account the changes between 1984 and 1985. The larger the difference between the sum of the two sub-periods and the whole period, the greater the changes in 1985. This also applies to Table 4.3 for sown areas.

** Figures in brackets represent the percentage increase between 1978 and 1990.

Source: SSB, *ZTN*, 1991, p.340, p.346 and p.353.

Figure 4.2 Changes in Grain Outputs, 1978-1990



Changes in sown areas for the respective grain crops also varied. Table 4.3 shows that between 1978 and 1990, total sown areas decreased by 104.82 million mu. Of this decrease, 20.34 million mu was the result of a decline in rice sown area, and the remainder can be attributed to the decrease in miscellaneous grains. The sown areas of wheat and corn did not decrease. Instead, they increased by 5.38 percent and 7.21 percent, respectively. Taking the three major crops as a whole, the combined sown areas increased slightly during the period studied, indicating an effort to stabilise sown areas for the key grains. In contrast to the major grain crops, the sown areas of miscellaneous crops experienced a large decline during this period.

Table 4.3 Changes in Grain Sown Areas, 1978-1990

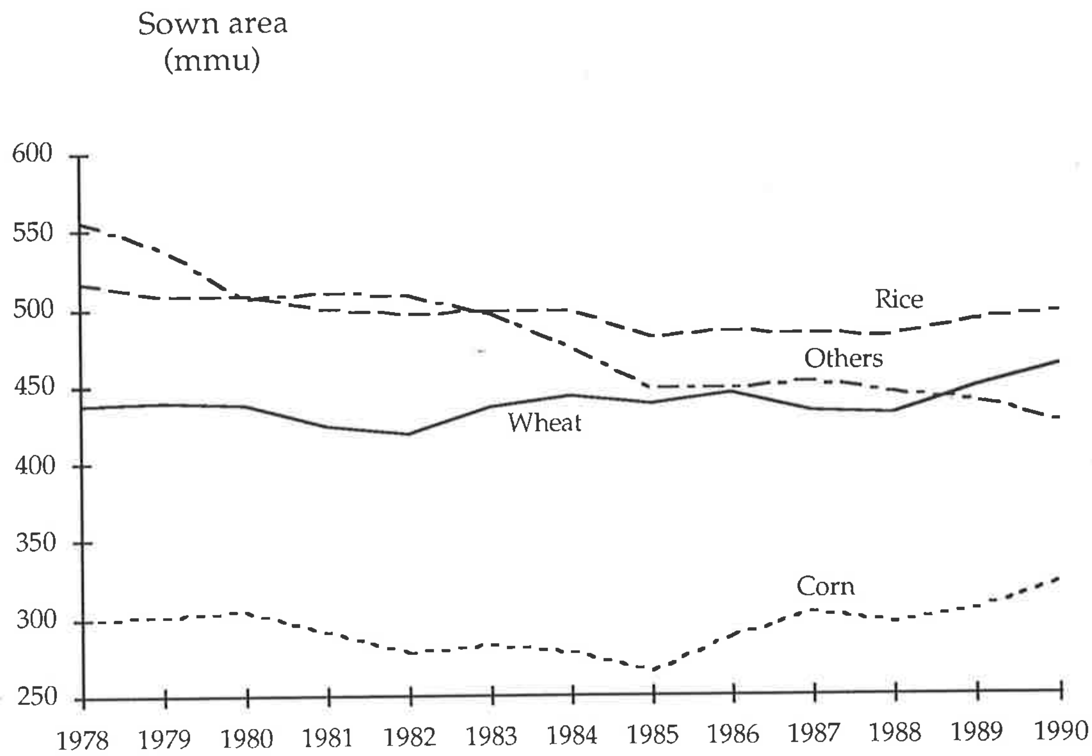
(million mu)

Year	Total	Wheat	Rice	Corn	Miscellaneous
1978	1808.81	437.74	516.31	299.42	555.34
1979	1788.94	440.35	508.09	301.99	538.51
1980	1758.15	438.42	508.18	305.29	506.26
1981	1724.37	424.60	499.42	291.37	508.98
1982	1701.94	419.33	496.07	278.15	508.39
1983	1710.71	435.75	497.05	282.36	495.55
1984	1693.26	443.65	497.68	278.05	473.88
1985	1632.68	438.27	481.05	265.41	447.95
1986	1663.99	444.24	483.99	286.86	448.90
1987	1669.02	431.97	482.89	303.18	450.98
1988	1651.84	431.77	479.81	295.38	444.88
1989	1683.07	447.62	490.51	305.30	439.64
1990	1703.99	461.30	495.97	321.02	425.70
Change					
1978-84	-115.55	5.91	-18.63	-21.37	-81.46
1985-90	71.31	23.03	14.92	55.61	22.25
1978-90	-104.82 (-5.79)*	23.56 (5.38)	- 20.34 (-3.94)	21.60 (7.21)	-129.64 (-23.34)

* Figures in brackets are the percentage changes between 1978 and 1990.

Source: Same as in Table 4.2.

Figure 4.3 Changes in Grain Sown Areas, 1978-1990



Differences in changes in sown areas for the respective grain crops can be observed more clearly from Figure 4.3. Generally speaking, the sown area of wheat was relatively stable over the whole period studied. For miscellaneous grain crops, the decrease in the sown area was a trend evident over the years. However, it is also noted that the rapid decrease occurred in the early years of the reforms. After 1985 the decrease was only minor. Changes in the sown areas of rice and corn altered during the two sub-periods. In the early 1980s, although the sown areas of rice and corn both declined, this was more prominent for corn. After 1985, the sown area of rice remained relatively stable, whereas the sown area of corn increased significantly. The difference in the changes in sown areas among grain crops implies that the production behaviour of farmers was not the same for different grain crops during the two sub-periods.

4.3.2 Structural Changes in Grain Production

Owing to variations in sown areas and output among different grain crops and over time, the structure of grain production has experienced changes. Tables 4.4 and 4.5, and Figures 4.4 and 4.5 show the details of these changes.

Table 4.4 The Relative Shares of Sown Area of Selected Grain Crops, 1978 , 1985 and 1990

(mmu)

	1978	%	1985	%	1990	%
Total	1808.81		1632.68		1701.99	
Rice	516.31	28.54	481.05	29.46	495.97	29.14
Wheat	437.74	24.20	438.27	26.84	461.30	27.10
Corn	299.42	16.55	265.41	16.26	321.02	18.86
Miscellaneous	555.34	30.70	447.95	27.44	423.70	24.89

Source: same as in Table 4.2.

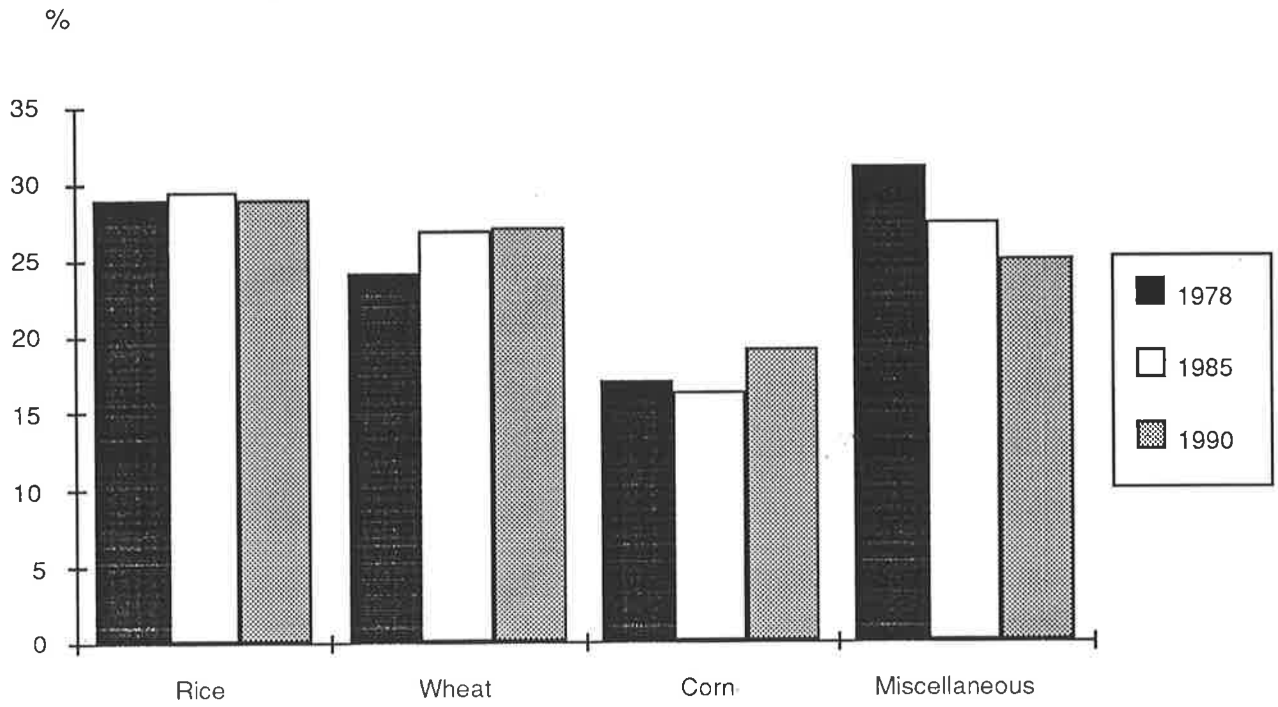
Table 4.5 The Relative Shares of Output of Selected Grain Crops, 1978, 1985 and 1990

(mmt)

	1978	%	1985	%	1990	%
Total	304.77		379.11		446.24	
Rice	136.93	44.93	168.57	44.46	189.33	42.43
Wheat	53.84	17.67	85.81	22.63	98.23	22.01
Corn	55.95	18.36	63.88	16.85	96.82	21.70
Miscellaneous	58.05	19.05	60.85	16.05	60.86	13.64

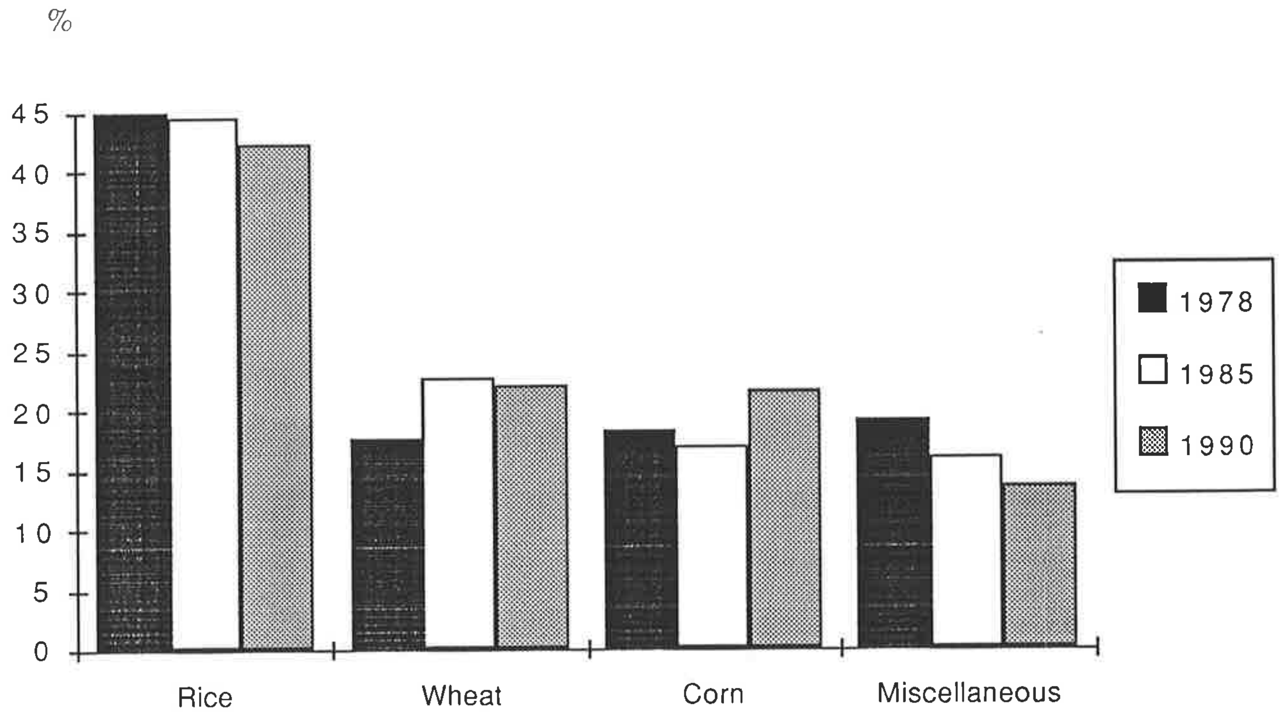
Source: Same as in Table 4.2.

Figure 4.4 The Relative Shares of Sown Area of Selected Grain Crops, 1978, 1985 and 1990



Source: Same as Table 4.4.

Figure 4.5 The Relative Shares of Output of Selected Grain Crops, 1978, 1985 and 1990



Source: Same as Table 4.5.

Between 1978 and 1990, the share of sown area of rice in total grain sown areas was relatively stable. The share of sown areas of wheat and corn increased by 2.9 percent and 2.31 percent respectively. Figure 4.4 however also shows that these increases occurred in different sub-periods. The increase in the share of wheat sown area mainly occurred in the earlier sub-period; in the second it was fairly stable. In contrast, during the first sub-period, the share of corn sown area decreased slightly, whereas during the second sub-period, its share increased by 2.6 percent. As for the miscellaneous grain crops, the share decreased constantly over the whole reform period.

In accordance with the changes in sown areas, the relative shares of output for respective grain crops also changed over the period studied. Between 1978 and 1990, the share of rice in total grain output decreased from 44.93 percent to 42.43 percent. The share of miscellaneous grains decreased from 19.05 percent to 13.64 percent. In contrast, the shares of wheat and corn increased by 4.34 percent and 3.34 percent, respectively. However, the main increase in wheat occurred in the first sub-period, while for corn, the increase was more significant in the second sub-period. This feature, as will be analysed in later chapters, is related partly to the changes in demand for different types of grain. The increased demand for feed grain (mainly corn) during the second sub-period is the result of the increasing consumption of meat and dairy products.

A comparison between the relative shares of sown area and output for respective grain crops shows large gaps between the two. This is particularly evident in rice and miscellaneous grain crops. For example, in 1978 the rice sown area was 28.54 percent of the total grain sown area, whereas the share of output was 44.93 percent, reflecting the high yield of rice. This may explain the relatively small decrease in rice sown area, because ensuring stable food supply has been always the priority task in China. Similarly, this could also be the reason for the large decrease in the share of sown areas of miscellaneous grain crops, which have relatively low yields. As shown in Table 4.4 and Table 4.5, the share of sown areas of miscellaneous grain crops was 30.7 percent in 1978, whereas the share of output was only 19.05 percent. From the viewpoint of increasing total output, the decrease in share of miscellaneous grain crops in grain production during the period studied would have been a rational adjustment. Such an adjustment is nevertheless also partly the result of administrative intervention. One of the consequences of this intervention was the price differentials between crops. According to the State Price Bureau's survey, the relative profits per unit area of most miscellaneous grain crops were lower than wheat, rice and corn (SPB, *QNCSDZH*, 1981-1990).

It is noticed that after 1985 the reduction of the sown area of miscellaneous grain crops slowed down and the output was relatively stable. This trend was associated with an increase in demand and subsequent rises in the prices for miscellaneous grain crops.[2] This situation implies that further increases in the sown areas of wheat and corn may become difficult and that the potential for increasing total output through sown area substitution is also limited.

It is also worth noting that for rice and corn, the scale of the changes in sown areas and output are different. As illustrated in Figure 4.4 and 4.5, although the share of rice sown area was relatively stable during the second sub-period, the share of output decreased. For corn, there was a relatively

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[2] It has been reported in recent years, that the demand for miscellaneous crops, such as various types of beans and millet has been increasing, which has pushed the prices up for these crops (Sichuan Grain and Oil Wholesale Market and the Centre for Business Information, 1993; Guo Guorong and Li Ji, 1994).

small increase in the share of sown area, but a larger increase in the share of output. This feature indicates a rapid improvement in corn yield during the second sub-period, which may also imply a better performance of production. This hypothesis will be tested in Chapter 7.

4.4 Provincial Grain Production Changes Between 1978 and 1990

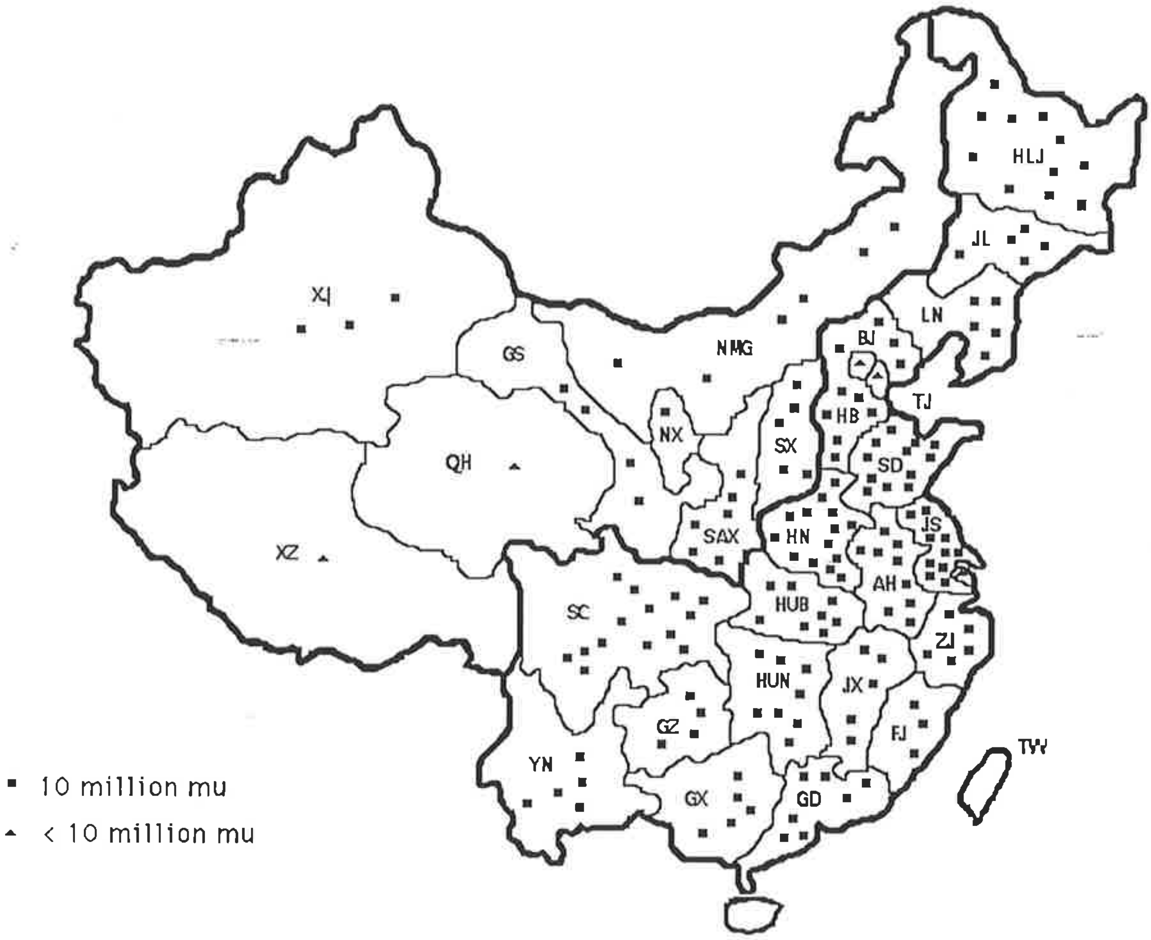
In China, great differences in natural environment, resource endowment and socio-economic conditions have generated significant variations in grain production in terms of the crops produced, inputs applied and yields obtained in different provinces. There were significant differences in grain production among provinces in terms of the pace of growth and when the growth occurred. This section examines these variations and posits some questions to be dealt with later in this study.

4.4.1 The Spatial Distribution of Grain Production

The spatial distribution of grain production in China is extremely uneven. Grain production is heavily biased towards the southeast provinces. Dividing China into two roughly equal parts as shown in Map 4.1 and Map 4.2, 84.73 percent of total grain sown areas and 89.41 percent of grain output are concentrated in the southeast. Only 15.27 percent of sown areas and 10.59 percent of output are in the northwest (SSB, *ZNTN*, 1991). Map 4.2 shows that of the 16 provinces with grain output over 10 million tonnes, only Shaanxi is located in the northwest compared to 15 provinces in the southeast.[3] This spatial distribution is closely related to China's overall geographical features, including natural conditions, such as temperature, rainfall, topography,

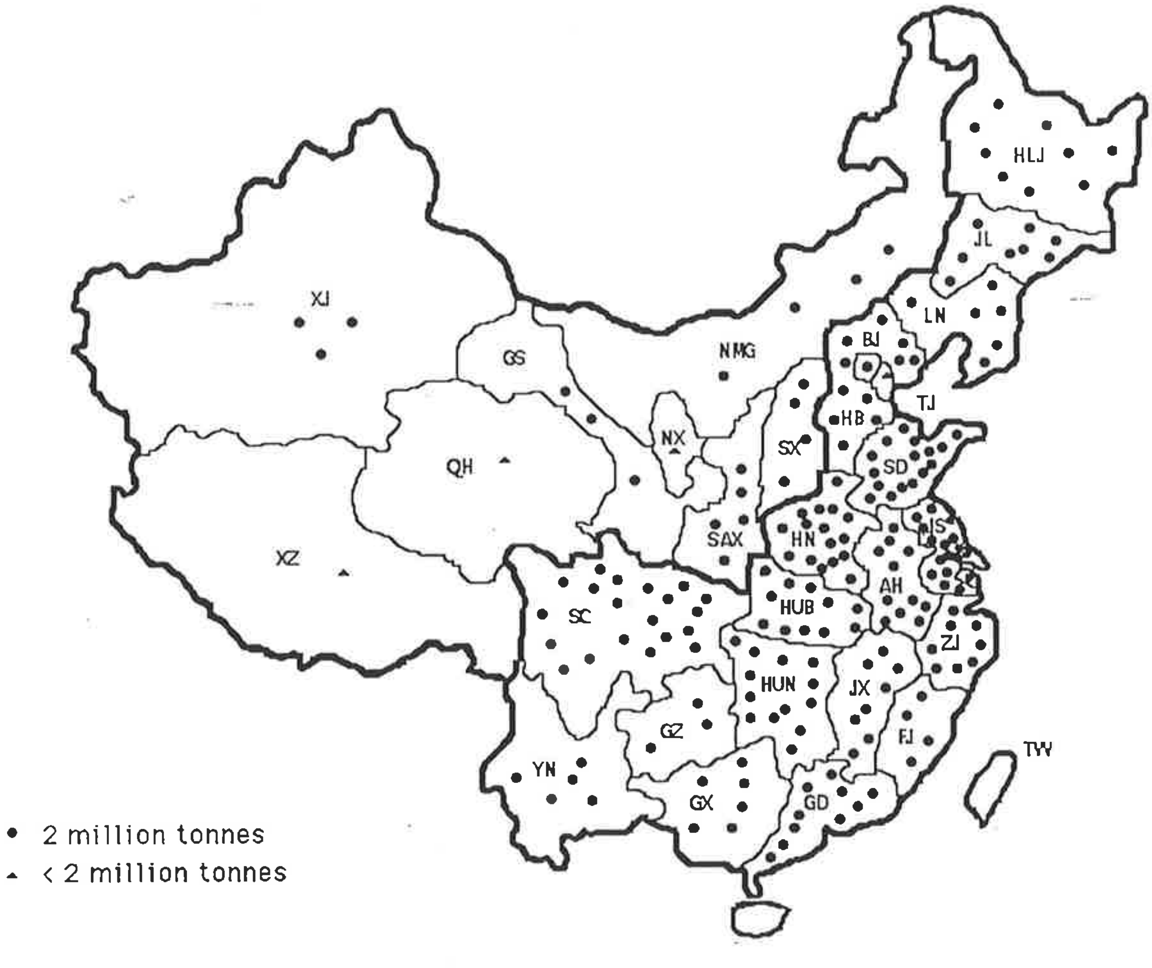
[3] The 16 provinces with grain output over 10 million tonnes are Hebei, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Sichuan and Shaanxi.

Map 4.1. Spatial Distribution of Grain Sown Area by Provinces, 1990



Source: SSB, *ZTN*, 1991, p.342.

Map 4.2. Spatial Distribution of Grain Output by Provinces, 1990



Source: SSB, *ZTN*, 1991, p.350.

soil types and so on and various socio-economic conditions, including the development of the rural economy and the farmers' economic status. As the southeast provinces occupy such a decisive position in China's grain production, the present study gives particular attention to grain production in this area.

4.4.2 Changes in Provincial Grain Production

Table 4.6 shows the changes in sown areas in different provinces between 1978 and 1990. In most provinces, grain sown areas declined. This is consistent with the changes at the national level. The three municipalities, Beijing, Tianjin and Shanghai, and Guangdong, Guangxi, Xinjiang and Hebei provinces had large declines of more than 13 percent. In the remaining provinces, grain sown areas went down by 3-7 percent, except for Heilongjiang, Jiangsu and Anhui, where the sown areas increased slightly. Table 4.6, however, does not show clear spatial patterns in changes in grain sown areas. This is partly because of the figures in the table are the aggregate sown areas. When these figures are disaggregated into respective grain crops, some patterns emerge. This will be examined in Chapter 5.

The two sub-periods in national grain production identified earlier can also be seen clearly at the provincial level. In most provinces, the drastic decline in grain sown areas occurred in the first sub-period. In the second sub-period, most provinces reported an increase, reflecting a partial recovery of sown areas.

In Table 4.6, the sum of the figures for the two sub-periods are inconsistent with the figures for the whole period in most provinces. This reflects the drastic decline in grain sown areas in 1985 compared to 1984.

Table 4.6 Changes in Provincial Grain Sown Areas, 1978-1990

	1978 (1000 mu)	1990 (1000 mu)	1978-84 %	1985-1990 %	1978-90 %
National	1808810	1703990	-6.38	4.36	-5.79
Beijing	8416	7266	-6.78	-5.49	-13.66
Tianjin	9016	6868	-18.98	2.59	-23.82
Hebei	119240	102417	-16.27	4.90	-14.11
Shanxi	55390	49354	-9.85	7.15	-10.90
Neimenggu	61407	58117	-8.10	11.68	-5.36
Liaoning	49909	46824	-6.86	7.42	-6.18
Jilin	54047	52888	-2.81	6.89	-2.14
Heilongjiang	107014	111300	3.09	2.75	4.01
Shanghai	7683	6257	-5.12	-5.00	-18.56
Jiangsu	94664	95445	4.06	-1.08	0.83
Zhejiang	50251	48990	3.97	-0.15	-2.51
Anhui	92801	93691	0.09	5.56	0.96
Fujian	33191	31209	-8.85	9.26	-5.97
Jiangxi	57312	55489	-2.80	1.30	-3.18
Shandong	132119	122279	-11.07	2.06	-7.45
Henan	136851	139741	-1.39	3.08	2.11
Hubei	83172	78000	-4.52	1.77	-6.22
Hunan	87422	80485	-7.50	3.81	-7.94
Guangdong	87381	68457	-16.78	2.20	-21.66
Guangxi	64270	54599	-13.88	5.30	-15.05
Sichuan	159929	147416	-8.10	4.46	-7.82
Guizhou	40470	38148	-14.08	13.02	-5.74
Yunnan	55168	54334	-6.43	8.39	-1.51
Xizang	3075	2876	-6.47	-1.22	-6.47
Shaanxi	67319	62020	-10.58	4.08	-7.87
Gansu	44939	43127	-5.97	3.48	-4.03
Qinghai	6521	6005	-6.61	3.33	-7.91
Ningxia	11342	10853	-9.94	10.16	-4.31
Xinjiang	35007	27533	-14.60	-1.44	-21.35

Source: USDA, *ERS*.

Table 4.7 Changes in Provincial Grain Output, 1978-1990

Areas	1978 (1000 tonnes)	1990 (1000 tonnes)	1978-1984 %	1985-1990 %	1978-1990 %
National	304770	446240	33.64	17.70	46.42
Beijing	1860	2646	16.94	20.44	42.26
Tianjin	1170	1889	12.39	34.45	61.45
Hebei	16880	22769	10.78	15.78	34.89
Shanxi	6740	9690	29.38	17.78	43.77
Neimenggu	4985	9730	19.26	61.07	95.19
Liaoning	11170	14947	27.66	53.15	33.81
Jilin	9145	20465	78.73	67.02	123.78
Heilongjiang	14775	23125	18.95	61.71	56.51
Shanghai	2610	2395	-3.26	12.02	-8.24
Jiangsu	22900	32308	46.44	3.34	41.08
Zhejiang	14670	15861	23.86	-2.17	8.12
Anhui	14825	24572	48.57	13.34	65.75
Fujian	7260	8796	17.15	10.73	21.16
Jiangxi	10500	16582	47.52	8.13	57.92
Shandong	22880	33549	32.87	6.92	46.63
Henan	20975	33037	37.95	21.89	57.51
Hubei	17255	24750	31.15	11.68	43.44
Hunan	19000	26514	37.53	5.45	39.55
Guangdong	16320	20665	20.86	18.90	26.62
Guangxi	10825	13631	12.06	22.02	25.92
Sichuan	31965	42668	27.62	11.38	33.48
Guizhou	6435	7210	17.79	21.18	12.04
Yunnan	8640	10572	16.32	13.07	22.36
Xizang	515	555	-3.88	4.52	7.77
Shaanxi	8000	10707	27.94	12.48	33.84
Gansu	4910	6907	9.88	30.20	40.67
Qinghai	905	1140	11.60	13.66	25.97
Ningxia	1170	1901	31.62	36.27	62.48
Xinjiang	3745	6662	32.71	33.56	77.89

Source: USDA, *ERS*.

Despite the general recovery of grain sown areas in the second sub-period, the decreases over the whole period were still larger than the first sub-period for many provinces. Nevertheless, the differences between the figures for 1978-84 and 1978-90 were relatively small, implying that in 1990 the sown area of grain had stabilised around the level of 1984.

Table 4.7 shows that between 1978 and 1990, grain output increased in all provinces (except for Shanghai), but the degree of the increases differed significantly. For example, in Jilin province, output more than doubled, whereas in Zhejiang it increased by only 8 percent. These differences in the growth of grain output did not, however, exhibit a significant spatial pattern over the whole period of the reforms. This again becomes relatively clear when looking at changes in respective grain crops.

Nevertheless, observing the changes in the two sub-periods reveals some noticeable features. During the first sub-period, the large increases in grain output occurred mainly in the large grain producing provinces, including Jiangsu, Anhui, Jiangxi, Shandong, Henan, Hubei, Hunan and Sichuan, all with growth over 30 percent. In the second sub-period, their output increased only modestly. In Jiangsu, Shandong and Hunan, the growth was less than 7 percent. Due to their important role in national grain production, the growth patterns of these provinces had a strong influence on the overall national grain situation. It is also noticed that in Neimenggu, Liaoning, Jilin, Heilongjiang and Gansu, the growth in the first sub-period was modest, whereas the increase in the second sub-period was remarkable. Bearing in mind that these provinces are the most important corn producers in China, the rapid growth in corn output at the national level during the second sub-period was obviously attributable to the growth in these provinces. In many other northwest provinces, the growth of grain output over the whole period was relatively smooth. Because of their small shares in national grain production, they had no significant influence on the grain situation at the national level.

4.5 Summary and Implications

This examination of grain production over the reform period has revealed several important features, which can be summarised as follows:

First, during the reform period, great changes have taken place in China's grain production. One of the most significant aspects has been the remarkable increase in grain output at a time when sown areas decreased. This indicates a great increase in grain yield or land productivity. It also implies that increasing yields have been the sole contributor to the growth of grain output during the period studied.

Second, uneven development of grain production has also been a prominent feature of the reform period. This is reflected in a number of aspects, including the existence of two sub-periods of change in grain output and sown areas, the variations in the changes in respective grain crops and the diversities among the provinces. Between 1978 and 1984, grain output grew rapidly. It declined suddenly in 1985 and recovered slowly in the following years. Changes in sown areas followed a reverse pattern. The drastic decrease mainly occurred in the first sub-period, when grain output increased rapidly. In the second sub-period, sown areas recovered. The uneven changes in output and sown areas have resulted in two distinct sub-periods over the whole period studied.

The third feature is that, during the period studied, the differences between provinces in grain production have become increasingly significant. Analyses show that most of the increased grain output after 1978 came from the large grain producing provinces in the central and the coastal areas. The contributions of the other provinces were much less significant.

The changes in grain output during the period studied, ultimately, were the combined result of changes in inputs and changes in the productivity of the inputs. To measure quantitatively the contribution of each factor, in particular the contribution of changes in total factor productivity, to changes in grain output, it is necessary to estimate the output elasticity with respect to each input. However, before doing this, it is also necessary to look first at growth patterns of yield, since the increased output during the period studied was mainly the result of the increase in yield.

Chapter 5

Analyses of the Growth Patterns of Grain Yields

5.1 Introduction

Yield is the output per unit of land.[1] Owing to the scarcity of arable land in China, increasing grain yield has long been the most important means of raising total output, and great efforts have been made to achieve this goal. The aim of this chapter is to examine changes in grain yields at both the national and provincial level between 1978 and 1990. Attention is focused directly on the responses of grain yields to labour and capital input changes and on the impact of weather fluctuations.

In addition, this chapter also examines the effect of differences in the natural environment on provincial grain production.[2] The variation in the crop structure of grain production among provinces is one of the significant consequences of these differences. This is due to the fact that each grain variety requires certain conditions of water, temperature, topography and soil type. For this reason, grain production in one area is often dominated by one or two major grain crops. The different genetic yields of individual grain crops have a strong impact on aggregate yields in different areas. Moreover,

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1 Considering the multiple cropping nature of China's grain production and the lack of accurate data for cultivated land, this study uses sown area instead of cultivated land. Grain yield is defined as the output of per unit sown area.

2 Here the natural environment (conditions) refers to climate, topography and soil types. Weather fluctuations are considered separately in this study, though they are one of the characteristics of natural environments.

the yields of any particular crop also vary between provinces due to different levels of suitability of natural conditions for the crop. Investigating the effect of natural conditions on the spatial distribution and level of grain yield is of significance for understanding disparities in provincial grain production and productivity.

This chapter is organised as follows: Section 2 examines changes in grain yields and investigates the effects of input changes and weather fluctuations on grain yield in the country as a whole. It draws attention to changes in labour input. The effect of the existence of surplus labour on the estimation of the elasticity of labour input will be foreshadowed. Section 3 examines the structure of provincial grain production by grain types and analyses the effects of some natural factors on this. The purpose is to show the effect of this structure on provincial aggregate yield and to demonstrate the need to consider provincial disparities in grain yield at a disaggregate level. The effect of natural conditions on disaggregate grain yields in different provinces will also be examined. This is followed by an investigation in Section 4 of growth patterns and disparities in disaggregate provincial grain yields. Section 5 summarises the major conclusions drawn from this analysis.

5.2 Analysis of Growth Patterns of National Grain Yields

In reviewing the development of grain production during the reform period in Chapter 4, the uneven course of the growth and the divisions into two sub-periods have been identified. As the sown area of grain declined over the period studied, the increased grain output relied primarily on increase in yields. It can be expected therefore that the growth patterns of grain yields would have similar trends to those of output. This section first examines this relationship and then identifies some of the variations among respective grain crops. This is followed by a discussion of input changes and yield responses. Some implications for technological progress in grain production will be outlined. The impact of weather fluctuations on growth patterns of yield will also be examined.

5.2.1 Changes in National Grain Yields

Between 1978 and 1990, China's grain yields experienced significant growth. Table 5.1 shows that during this period, the average grain yield increased by 55 percent, representing a 93 kg/mu increase compared with 1978.

Despite the significant improvement in grain yields, the course of growth was uneven. For the aggregate grain yield, the large increase mainly occurred during the period between 1978 and 1984. Between 1985 and 1989, it fluctuated around the 1984 level. In 1990, there was a large increase. This general trend can also be observed in all the respective grain crops. The growth patterns of grain yield were thus generally consistent with the growth patterns exhibited in grain output as reviewed in Chapter 4.

Variations among different grain crops are, however, significant. During the period studied, the yield of rice increased by 117 kg/mu, wheat by 90 kg/mu and corn by 105 kg/mu. In contrast, the yield of miscellaneous grain crops increased by only 40.5 kg/mu, significantly less than the others.[3] As rice, wheat and corn are the major grain crops in China, the remarkable

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[3] As shown in Table 1, the growth rate of the yield of miscellaneous grain crops is also the lowest compared with other grain crops. For this reason, the small figure for the increase in miscellaneous grain yield cannot be fully explained by their relatively low genetic yields. It may also reflect the different efforts made to produce different grain crops. This issue will be further discussed later in this study.

increases in the yields of these grain crops have been the main contributors to the great increase in the aggregate grain yield during the period studied.

Table 5.1 Changes in Grain Yields, 1978-1990

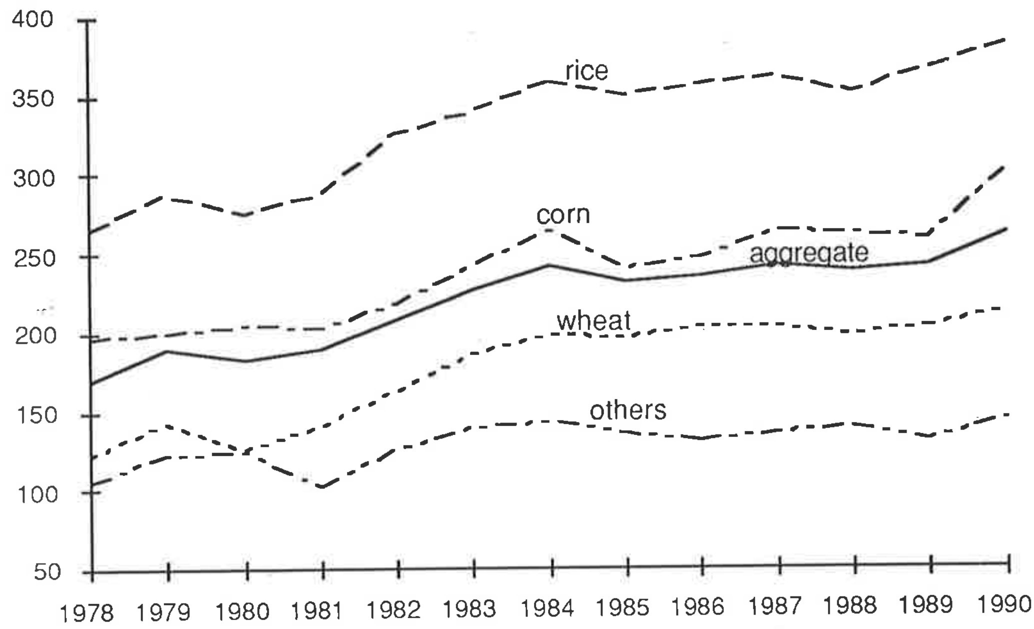
(kg/mu)

Year	Aggregate	Rice	Wheat	Corn	Others
1978	169	265	123	197	105
1979	189	288	143	199	122
1980	183	276	126	205	124
1981	189	288	141	203	103
1982	209	326	163	218	126
1983	227	340	187	242	139
1984	241	358	198	264	143
1985	232	350	196	240	136
1986	235	356	203	247	130
1987	242	361	203	263	135
1988	239	352	198	262	140
1989	242	367	203	259	131
1990	262	382	213	302	145
Change					
1978-90	93	117	90	105	40
%	55	44	73	53	38
1978-84	72	93	75	67	38
1985-90	30	32	17	62	9

Source: SSB, *ZTN*, 1991, p.353.

Figure 5.1 Changes in Grain Yields, 1978-1990

Yield (kg/mu)



Source: Table 5.1.

Observing the growth patterns of individual grain yields reveals that the fluctuations in rice and wheat yields were less than those of corn. For the former two, no sharp fluctuations occurred over the period studied. This is consistent with the situation exhibited in changes in output. In the case of corn, during the first sub-period, the yield increased relatively slowly compared with rice and wheat, whereas during the second sub-period, the growth continued with significant fluctuations. In 1990 the corn yield experienced the largest increase among all the grain crops. As will be detailed below, these fluctuations are closely related to changes in weather conditions, inputs and economic incentives.

The different situation in respective grain crops is, however, likely to be related to the self-sufficiency characteristic of farm household grain production. For most farm households, self-consumed grain is produced by themselves. The large proportion of wheat and rice in the total direct food grain consumption means that farmers have to produce these grains to ensure their own consumption. This may be a factor stabilising the output and yield of wheat and rice. This is particularly so taking into consideration that household food consumption accounts for a large proportion in total household grain output.[4]

5.2.2 Input Changes, Weather Fluctuations and the Growth Patterns of Grain Yields

There are numerous studies of the effects of government policies on the extraordinary course of grain production during the reform period. Most scholars believe that radical changes in government policies, in particular, in institutional, pricing and marketing systems, have been responsible for the uneven growth of grain production. A commonly accepted view is that the policies, mainly the implementation of the HRS and the increase in grain purchase prices during the early years of the reforms stimulated peasants' enthusiasm for grain production. This resulted in a sudden boost in grain output. The stagnation of grain production between 1985 and 1989 was associated with the depletion of the one-off gains of the institutional reforms and the unfavourable marketing policies implemented in 1985. The poor weather conditions, however, were also partly responsible. This study shares these views. It takes the analysis further, however, by examining the impact of inconsistent marketing policies and different levels of central control over the production of respective grain crops on the growth patterns of total factor productivity. Moreover, it also investigates farmers' responses to the various

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4 The marketed volume of grain only accounts for about 30 percent of the total output (SSB, *ZTN*, 1991, p.389).

changes in economic incentives caused by the reforms and the effect of those responses on changes in the total factor productivity of grain production. These analyses will be undertaken in Chapter 7 and Chapter 8, respectively.

One point worth bearing in mind is that the effects of marketing and pricing policies on grain production usually act through changes in production inputs. It is therefore of significance to examine input changes and to observe the responsiveness of yields to these changes.

1) Changes in Labour and Material Inputs

Before discussing changes in inputs, it is necessary to specify the concept of the "standard labour day" applied in this study. According to Liu Fuyuan (1983), the standard labour day is defined as eight hours work at a medium level of labour intensity and skill by an adult male labourer. Labour provided by different age groups and genders are converted into standard labour day equivalents. This concept provides a standard means to measure labour input in agricultural production and has been commonly used in rural household surveys in China in recent years. [5]

Table 5.2, which is based on the household survey, shows that between 1978 and 1990, labour input per unit area declined by approximately 50 percent for all the grain crops, indicating a great increase in labour productivity. The major decrease, however, occurred in the early years of the reform period. After 1985, labour input was relatively stable. [6]

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[5] The merits and problems of the standard labour day measurement will be discussed in Chapter 6.

[6] It is, however, noticed that for wheat and corn, labour input per unit area increased slightly in 1990. One of the reasons for this increase was perhaps the effect of the government austerity policy and the depressed situation in the rural non-grain sectors, in particular in rural industries. In that year, a large number of labourers who had shifted to other sectors in the previous years flowed back to the grain sector. According to the official statistics, in 1989,

Table 5.2 Standard Labour Days and Material Inputs* Per Unit Sown Area, 1978-1990

Year	Average**		Rice		Wheat		Corn	
	labour days	material yuan/mu	labour days	material yuan/mu	labour days	material yuan/mu	labour days	material yuan/mu
1978	30.53	23.04	38.10	29.99	30.70	25.14	31.10	22.56
1979								
1980	24.23	24.99	31.70	32.71	23.10	28.96	24.90	24.22
1981	20.30	22.86	29.30	32.52	20.40	29.21	21.70	24.22
1982	17.40	23.95	25.40	35.49	17.70	29.91	18.90	25.05
1983	16.57	25.09	24.20	35.54	16.09	30.72	18.30	27.18
1984	15.95	25.48	22.68	36.70	15.78	30.86	16.85	26.97
1985	15.28	24.92	21.88	36.00	14.53	31.09	16.31	26.72
1986	14.85	25.66	21.60	37.74	13.72	32.84	16.28	27.86
1987	14.67	26.98	21.02	40.17	13.51	34.15	16.29	30.49
1988	14.37	27.92	21.13	44.96	13.47	34.27	16.54	30.74
1989	14.30	29.12	20.97	47.88	13.55	36.46	16.78	32.73
1990	14.70	30.15	20.60	47.32	14.00	38.43	17.30	34.92
Change 1978-90	-15.83	7.11	-17.50	17.33	-16.70	13.29	-13.80	12.36
1978-84	-14.58	2.44	-15.42	6.71	-14.92	5.72	-14.25	4.41
1985-90	-1.25	4.67	-1.28	11.32	-0.53	7.34	0.99	8.19

* Material inputs refer to total expenses, including the costs for fertiliser, seeds, machinery, irrigation, pesticide and so forth. The figures in the table have been adjusted to the 1978 constant price.
** Figures for 1978 and 1980 are the average for rice, wheat, corn and soybean. Figures for the remaining years are the average for rice, wheat, corn, soybean, potatoes and millet.

Source: Data for 1978 and 1980 are from the SPB, *ZWN*, 1989, pp.73-74. Other data are from the SPB, *QNCSZH*, 1981-1991.

The early years of the reform were characterised by the transfer from the People's Commune System to the HRS. The rapid decrease in labour input during this period was closely related to the implementation of the HRS. As mentioned in Chapter 2, under the Peoples' Commune System, farmers' incomes were determined primarily by the work points they earned. This, in effect, encouraged farmers to supply more labour, no matter whether the increased labour input was able to increase output or not. This could be one of the reasons why the People's Commune System was successful in

the labour force in rural industries and construction decreased by 1.18 million. By contrast, labourers in the crop farming sector increased by 9.85 million (SSB, *ZNTN*, 1990).

mobilising rural labourers but failed to use them efficiently. Under the HRS, farmers' incomes are determined by the work the household labourers do. Applying more labour is no longer a means to increase household income if this increased labour does not generate extra output. In such circumstances, family labourers may either move out to seek other employment opportunities or reduce their labour hours per day or per year in order to have more leisure time. This led to the dramatic decrease in labour input in grain production measured in standard labour days during the early 1980s.

The stable figure for labour input for all grain crops during the second sub-period is, nevertheless, noticeable. Given the existence of surplus labour in rural areas, it is reasonable to assume that this stability reflects the point beyond which the marginal output of labour input is small or negligible.[7] If this is true, difficulties may arise in estimating the output elasticity of the labour input, as there may not be enough variations to allow regressions to capture the effect of labour input changes on output. Further discussion and testing of this point will be presented in Chapter 6.

Changes in material inputs experienced a different pattern to those in labour input. The survey shows that during the period studied, the average material inputs increased by more than 30 percent at 1978 constant prices. However, these increases mainly occurred after 1985. In the early years of the reforms, material inputs changed only slightly.

A comparison between aggregate grain and individual grain crops also shows significant variations. For material inputs, the increase in the average is

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[7] This assumption is based on the classical labour surplus theory, which argues that small farm households tend to keep the labour input level at the point where the marginal output (or productivity) of labour is zero or negligible. For theoretical analysis of surplus labour and the marginal product of labour input in agriculture, see Lewis, 1954; Fei and Ranis, 1964; and Meng Xin and Bai Nansheng, 1988.

smaller than that in the three major grain crops, suggesting a smaller increase in material inputs for miscellaneous grain crops. This feature is consistent with the point made in Chapter 4 that a greater effort has been made to produce the major grain crops.

All in all, two conclusive points can be drawn from Table 5.2. First, given the fact that there was a sharp decrease in labour inputs and a small increase in material inputs between 1978 and 1984, the increased grain yields during this period would have to be attributed to an improvement in total factor productivity. Second, whatever the effects of government pricing and marketing policies, it is a fact that between 1985 and 1990 more material inputs were applied per unit sown area and that labour inputs were relatively stable compared with the dramatic decline between 1978 and 1984. Therefore, the slow increase in grain yields and the consequent stagnation of grain output in the late 1980s cannot be entirely explained by the changes in pricing and marketing policies after 1985.

In examining the sources of the improvement of total factor productivity in the early years of the reforms, many scholars have pointed to the latent productivity, which was accumulated but constrained during the People's Commune period. The HRS released this latent productivity by allowing farmers to organise household resources more efficiently (Watson, 1987; Zheng Zhong, 1988; Carter and Zhong, 1988; Stavis, 1991 and Lin Yifu, 1992). In accepting this point, it was understood that the latent productivity would run out after several years of the reform. The situation after 1985 can be partly explained by the depletion of the accumulated productivity. Without significant technological progress in grain production to replace the previously accumulated productivity, further increase in grain yields would have to rely on more inputs. The uneven growth of grain yields during the reform period thus reflects a transition of Chinese grain production from intensive growth, which relied on the accumulation of the previous period to extensive growth, which required a new set of inputs. For this reason, even if the government had not changed the pricing and marketing policies after 1985, the dramatic growth in grain yields as experienced in the early years of the reform could not be maintained.

After 1985, studies of pricing and marketing policies and their effects on grain production dominated the main stream of academic research (See for example, Sicular, 1988a, 1992; Jin Hehui, 1990; Ke Bingsheng, 1991b; Zhou Zhangyue, 1993; Tang Renjian, 1993; Yang Hong, 1993; Watson, 1994a). There is little doubt about the positive effect of increasing grain prices on grain output. Farmers will apply more inputs if prices increase. However, as shown in Table 5.1 and Table 5.2, between 1985 and 1990, material inputs increased by 11.32 yuan/mu and 7.34 yuan/mu for rice and wheat, respectively. The corresponding yields increased by 32 kg/mu and 17 kg/mu. The ratio of increased output to increased capital input was less than 3 kg/yuan. The low ratio can be seen more clearly in the consumption of chemical fertiliser. According to the SPB survey (SPB, *QNCSZH*), during this period, chemical fertiliser input per mu for rice increased from 93.1 kg to 136.57 kg and for wheat, from 73.53 kg to 105.75 kg. The ratio of increased output to increased chemical fertiliser input was fairly low.[8] The experience of rice and wheat production during the later years of the 1980s implies that solely relying on increasing inputs to raise grain output is costly and therefore inefficient.

[8] This does not take into account any changes in the types of chemical fertiliser used. It also does not consider the effect of changes in other input factors, such as irrigation, seeds, organic fertiliser and pesticide on the effectiveness of the chemical fertiliser input. Further discussion of the input-output relationship for respective grain crops will be presented in Chapter 6.

Compared with the situation of rice and wheat, during the second sub-period, the corn yield experienced a relatively large increase of 62 kg/mu, though this occurred with a great fluctuation. During this period, material inputs increased by 8.19 yuan/mu, and the chemical fertiliser input increased by 35 kg/mu, not much different to the increase in the other two. This points to an improvement in technology during the second sub-period, though it is acknowledged that the yield of corn started from a low level compared to other countries.

2) Technological Changes

Technological improvement has been a factor in the development of China's grain production. This improvement can be seen in two aspects. One is the development and application of new varieties, hybrid seeds in particular. The other is the substitution of modern inputs for traditional inputs.[9] For respective grain crops, however, the pace of technological development and the effect of new technologies on increasing yields varied, resulting in variations in the growth patterns of yields over the years.

China's "green revolution" started in the mid 1970s, represented by the introduction of hybrid rice varieties (Song Jundong and Huang Ren, 1992). The basic characteristics of the hybrid varieties are high yield and early maturity, which are highly desired by farmers. The hybrid rice varieties were rapidly spread over the major rice-producing areas. The peak effect of the hybrid varieties came in the early 1980s and contributed to a remarkable increase in rice output during this period. Afterwards, the one-off effect of the

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[9] Although the increasing use of modern inputs does not necessarily mean technological progress, it is also true that in practice the effect of technological progress is often embodied by and realised through the application of modern inputs.

introduction of new varieties in increasing output was depleted. This was partly responsible for the subsequent slow-down in the growth of rice output.

For corn production, two significant technological advances occurred in the late 1980s - the adoption of hybrid corn varieties and the application of plastic film cover techniques. It is reported that under the same conditions, the corn yield in a plot covered by plastic film could be 25-30 percent higher than that without a film cover (Huang Peirui, et al, 1990; Song Jundong and Huang Ren, 1992). The application of these technologies contributed greatly to the rapid growth in corn output in the late 1980s.

Table 5.3 Areas Covered by Plastic Film and Planted with Hybrid Varieties

Year	Areas covered by plastic film (10 thousand mu)		Areas planted with hybrid varieties (10 thousand mu)	
	Rice	Corn	Rice	Corn
1986	443.1	146.6		
1987	544.1	596.7	17644	26746
1988	475.0	604.3	19927	26543
1989	533.9	839.6	20028	26995
1990	559.7	1314.0		

Source: Ministry of Agriculture, *ZNTZ*, 1989, p.89 and 1990, p.91.

Statistical data regarding technological changes are extremely inadequate in China. From the limited sources, shown in Table 5.3, it can be seen that there was a rapid increase in the areas covered by plastic film in corn production between 1986 and 1990. During this period, more than 85 percent of corn sown areas used hybrid varieties. The adoption of the new technologies has brought about significant development in corn production and lifted the corn yield from below the world average in 1980 to 27 percent higher than that average in 1988 (ECCAY, *ZNN*, 1987, p.486; 1990, p.576).

Compared with corn and rice production, technological improvement in wheat was relatively slow over the 1980s, particularly in the second half of the decade.[10] The effect of the new varieties and other modern inputs on increasing overall wheat yield was also not as remarkable as in the case of the other two crops. This may explain partly the relatively slow growth in the wheat yield. The different experience in rice, wheat and corn production underlines the importance of improving technology in supporting a growth of grain yields.

It needs to be pointed out that apart from the above technological advances, other technological developments involving soil improvement, chemical fertiliser application and irrigation expansion also contributed significantly to the growth of grain yields. For example, scientific research brought about a continuous improvement in the nutrient value of chemical fertilisers over the years. Efforts were devoted to studying more effective combinations of nitrogen (N), phosphorous (P) and Potash (K) fertilisers in different areas and for different crops. In addition, marked successes were achieved in improving low yield fields through water conservation project networks and through utilising irrigation and drainage facilities (ECCAY, *ZNN*, 1986, pp.71-72). Despite recognising the contributions of these developments to the growth of grain yields, the available data are not sufficient to carry out a systematic analysis of the effects of individual technological measures on respective grain crops. Overall, this study does not seek to analyse concrete technologies applied to China's grain production. The prime interest, as stated at the beginning, is to investigate the changes in

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10 This statement is based on the information provided in the *Chinese Agricultural Yearbook* (ECCAY, *ZNN*, 1980- 1992).

total factor productivity as a whole and their aggregate contributions to the development of respective grain crops.

3) Weather Fluctuations

The growth patterns of grain yields between 1978 and 1990 were also affected by the fluctuations in weather conditions. Figure 5.2 shows an inverse relationship between changes in yields and changes in the areas affected by natural disasters.[11] Between 1981 and 1984, the areas affected by natural disasters were small and tended to decline. Between 1985 and 1989, the affected areas were large and tended to increase. In 1990, relatively few areas were affected by natural disasters compared with the period between 1985 and 1989.[12] It seems clear that the rapid increase in grain yields in the early 1980s benefited partly from the favourable weather conditions. The slow increase in grain yields between 1985 and 1989 can be partly attributed to the harsh weather conditions during this period.

In summary, the uneven growth in national grain yields reflects a transition of Chinese grain production from relying on intensive growth to being more dependent on extensive growth, though the periodic changes in weather conditions during this period were also partly responsible. Without continual progress in agricultural technology, increasing grain yields (and, in turn, grain output), will have to rely on a larger set of new inputs. The experience during the late 1980s shows that the returns to increased material inputs were small. This result may suggest that government needs to put

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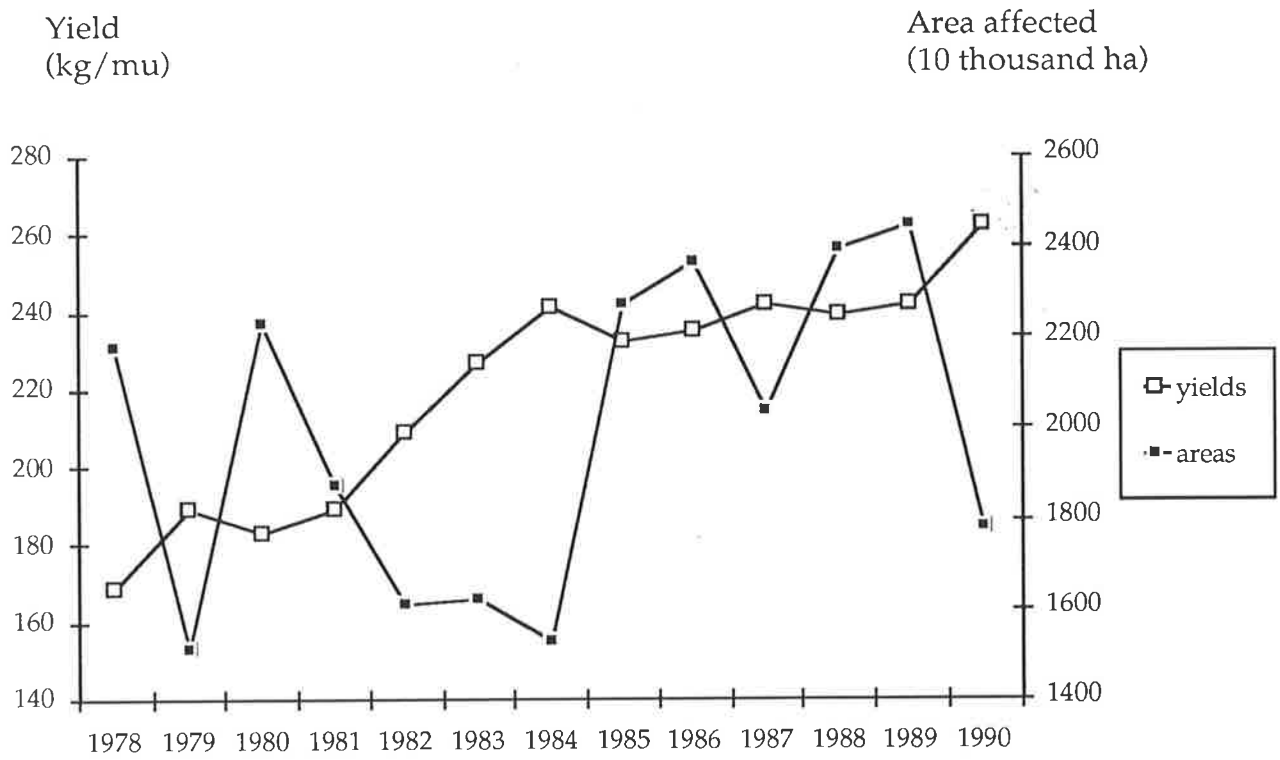
11 In Chinese statistics, areas affected by natural disasters (*chengzai mianji*) refer to the areas where the yield is more than 30 percent lower than the yield of a normal year.

12 The average areas affected by natural disasters between 1985 and 1989 were 345.4 million mu. In 1990, it was 267.3 million mu (SSB, *ZNTN*, 1988, 1991).

more effort into effectively organising resources for agricultural research and infrastructure and into promoting the application of new technologies.

Figure 5.2 Grain Yields and the Areas Affected by Natural Disasters, 1978-1990



Source: Data for yields are from Table 5.1. Data for areas affected by natural disasters are from SSB, *ZTN*, 1991, p.372.

5.3 The Spatial Distribution of Grain Crops and the Impact on Provincial Aggregate Grain Yields

The diversities among provinces in natural and socio-economic conditions result in great variations in the spatial distributions for different grain crops. This, in turn, leads to different aggregate yields in different provinces. This section first examines the spatial distribution of different grain crops. It then analyses the effect of the spatial distribution of different grain crops on the aggregate grain yields of different provinces. The effect of natural conditions on disaggregate yields among provinces is also examined. Implications for the study of provincial grain productivity will be drawn from the analysis.

5.3.1 The Spatial Distribution of Grain Crops

Table 5.4 and Table 5.5 show the quantities and shares of sown areas and output of respective grain crops by province. As can be seen, the spatial distribution of different grain crops varies significantly. In most provinces, grain production is dominated by one or two kinds of grain crops. For example, in Zhejiang, Fujian, Jiangxi, Hunan, Guangdong and Guangxi, rice sown areas account for more than 70 percent of the provincial total, other grain crops are generally unimportant. This feature implies that there are few alternative grain crops available in these provinces and that the potential for grain crop substitution may be limited. [13]

North of the Yangzi River, grain production is usually dominated by more than one grain crop. It is noticeable that in many northern provinces, wheat and corn are both important, indicating a relatively similar spatial distribution of these two crops. This feature can be observed in Beijing, Tianjin, Hebei, Shanxi, Neimenggu, Heilongjiang and Shandong. In other provinces, such as Jiangsu, Anhui and Hubei, rice and wheat are dominant grain crops. In Sichuan, Guizhou and Yunnan, grain production is almost equally shared by rice, wheat and corn, indicating great diversity in natural conditions within these provinces.

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[13] This is partly the result of natural conditions, which restrict the production of wheat and corn. South of the Yangzi River, temperature and rainfall are both too high for wheat and corn. The high PH soil in this area is also not suitable for wheat and corn. In previous studies of regional grain production, such as Buck (1937), Carter and Zhong (1988), and Committee of National Agricultural Division (1987), these regions were classified as rice regions.

Table 5.4 Quantities and Shares of Sown Areas of Grain Crops For Different Provinces, 1988-1990 (three year average)

	Total (1,000 mu)	Shares				
		Rice %	Wheat %	Corn %	Soybean %	Others %
National	1671990	29.2	26.3	18.4	7.0	18.4
Beijing	7277	7.3	38.5	45.7	2.5	6.1
Tianjin	6811	10.4	30.8	33.7	9.8	15.3
Hebei	101205	2.1	36.5	29.5	6.0	25.9
Shanxi	48932	0.3	30.9	18.6	7.3	42.9
Neimenggu	56043	1.5	28.0	19.1	8.3	43.2
Liaoning	46524	17.7	2.2	43.0	11.8	25.3
Jilin	51915	11.4	1.4	59.6	14.9	12.7
Heilongjiang	107843	8.5	21.8	27.4	31.4	11.0
Shanghai	6301	61.2	17.3	2.2	1.4	17.9
Jiangsu	96045	37.8	36.4	7.5	4.5	13.8
Zhejiang	48464	73.4	9.5	1.4	2.1	13.6
Anhui	92811	36.5	33.0	5.6	9.1	15.9
Fujian	30375	74.1	5.7	0.9	4.3	14.9
Jiangxi	54848	89.3	2.1	0.2	3.7	4.6
Shandong	121287	1.3	50.3	29.4	6.0	13.1
Henan	138086	4.6	51.4	21.9	7.2	14.9
Hubei	77325	46.7	26.0	7.5	3.3	16.5
Hunan	79530	81.8	3.6	2.2	2.5	9.8
Guangdong	69705	73.2	1.5	2.2	2.6	20.5
Guangxi	53625	69.9	0.7	6.0	5.6	17.8
Sichuan	144882	32.1	22.2	17.4	2.0	26.3
Guizhou	36948	29.8	15.4	24.3	5.2	25.3
Yunnan	52218	29.1	15.1	27.9	2.0	25.8
Xizang	2857	0.4	21.1	1.3	8.4	68.8
Shaanxi	61376	3.8	41.3	24.1	6.9	23.9
Gansu	42818	0.2	50.1	10.3	2.0	37.5
Qinghai	5902	0.0	53.2			46.8
Ningxia	10639	7.9	42.2	10.6	5.0	34.4
Xinjiang	27290	3.1	64.6	24.0	0.9	7.3

Source: The data for total sown areas are from the SSB, *ZNTN*, 1990, p.82, p.84, p.95, p.97; and 1991, p.90, p.92. The relative shares are calculated by the author based on the above sources.

Table 5.5 Quantities and Shares of Output of Grain Crops For Different Provinces, 1988-1990 (three year average)

	Total (1000 tons)	Shares				
		Rice %	Wheat %	Corn %	Soybean %	Others %
National	415956.7	43.2	22.0	20.3	2.6	11.1
Beijing	2461.3	9.3	37.5	48.5	1.2	3.5
Tianjin	1723.3	16.4	33.6	36.8	3.7	9.6
Hebei	21226.7	4.1	40.4	36.7	2.3	16.5
Shanxi	8888.0	0.6	30.6	32.3	3.2	33.3
Neimenggu	8010.3	2.6	25.6	41.4	5.5	24.8
Liaoning	12486.3	26.5	1.8	52.7	3.0	6.0
Jilin	16970.0	13.7	0.5	73.3	5.2	7.3
Heilongjiang	18590.0	14.1	19.4	40.9	17.9	7.7
Shanghai	2369.7	74.4	11.4	2.5	0.6	11.2
Jiangsu	32350.3	53.0	27.4	7.7	1.7	10.2
Zhejiang	15614.7	83.6	5.1	0.7	0.8	9.8
Anhui	23790.3	53.1	25.3	5.4	2.8	13.3
Fujian	8609.3	84.9	2.9	0.3	1.2	10.7
Jiangxi	15790.0	96.4	0.5	0.1	1.0	2.0
Shandong	31524.3	2.1	48.0	34.8	2.6	12.4
Henan	30387.0	7.3	53.3	26.0	2.6	10.8
Hubei	23682.7	71.3	6.5	4.6	1.1	6.5
Hunan	26065.0	93.1	1.0	0.9	1.0	4.0
Guangdong	19406.3	88.6	0.8	0.6	0.7	9.3
Guangxi	12263.0	88.4	0.2	8.5	1.1	1.9
Sichuan	40456.3	52.1	15.5	15.9	0.8	15.7
Guizhou	6884.3	49.0	8.2	25.7	1.8	15.3
Yunnan	9992.0	48.1	8.9	27.4	1.0	14.6
Xizang	536.7	0.6	25.4	1.6	7.1	65.4
Shaanxi	10291.0	9.4	43.6	30.4	2.8	13.9
Gansu	6428.3	0.3	52.9	17.3	1.2	28.2
Qinghai	1102.0		64.4			35.6
Ningxia	1754.3	28.1	40.8	19.4	1.4	10.4
Xinjiang	6304.0	6.6	58.7	30.7	0.6	3.5

Source: Same as Table 5.4.

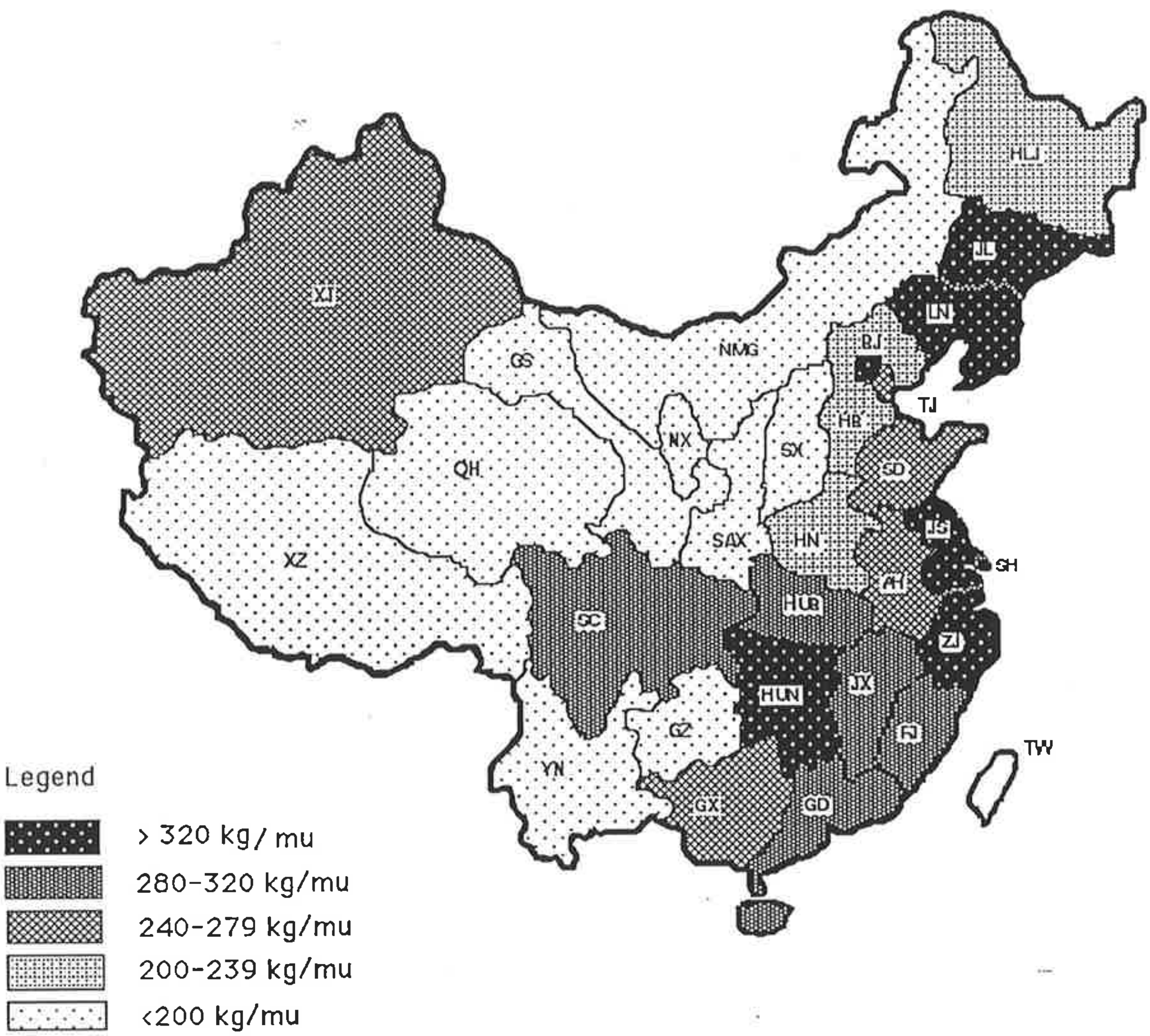
Miscellaneous grain crops are dominant only in provinces in the northwest, including Xizang, Qinghai, Shanxi and Neimenggu, where more than 40 percent sown areas are devoted to them. Apart from the constraints of the dry and harsh natural environment, the large share of miscellaneous grain crops in these provinces may also be related to their generally backward socio-economic development. According to the author's experience in Qinghai province, a remote inland area, the proportion of the sown area of miscellaneous crops was large but was decreasing over time and the proportion of wheat tended to increase. In general, the production of miscellaneous grain crops was carried out in an extensive manner. The extension of the wheat sown area was associated with relatively intensive management, better water supply conditions and more chemical fertiliser application. A similar situation has been reported in corn production in Shanxi province, where the adoption of film cover technology brought about a significant extension of corn sown area and an improvement in corn yield (Huang Peirui, et al, 1990; Song Jundong and Huang Ren, 1992). It seems therefore that the increase in sown area of wheat and corn in many northern provinces was associated with the development in the rural economy and the adoption of new technology. From this point of view, the overall proportional decrease in miscellaneous crops since the 1950s may have partly reflected this relationship. Nevertheless, as discussed previously, there may be a limit for the decline in the sown area of miscellaneous crops, with demand stabilising at a certain level. The situation after 1985 tends to support this point.

5.3.2 The Impact of Natural Conditions on Provincial Aggregate and Disaggregate Yields

In China, aggregate grain yields vary significantly among different provinces. These variations, however, have a defined pattern of spatial distribution. As shown in Map 5.1, the aggregate grain yields are generally higher in the southeast provinces than in the northwest. This is closely associated with natural conditions embodied by the combination of temperature, precipitation, topography and soil types.

The effects of natural conditions on provincial grain production can be demonstrated in two ways. First, given the level of technology, the location of a particular grain crop is determined by its biological requirements for water supply and temperature in the growing season. As a result, rice is concentrated in the south, wheat in the north, corn in the northeast and miscellaneous grain crops in the northwest. Noting that rice and corn have genetically higher yields than wheat and miscellaneous grain crops, average grain yields should be high in the areas where rice and corn account for a large proportion of grain production. In contrast, in the areas where miscellaneous grain crops predominate, average grain yields are expected to be lower. This means that the spatial distributions of grain crops directly influence the level of aggregate grain yields in different areas. The pattern shown in Map 5.1 demonstrates this relationship. To get a rough estimate of the extent to which the production structure affects aggregate yield, a linear regression was run by taking provincial aggregate yields as a dependent variable, and proportions of respective grain sown areas in the provincial total grain sown areas as an independent variable. The result shows that approximately 64 percent of the disparities among provincial grain yields can be explained by the different structure of grain production. Details of the estimation are attached in Appendix 5.A.

Map 5.1 Provincial Grain Yield, 1989/90



Source: SSB, *ZNTN*, 1991, p.113.

The second effect of natural conditions on grain yields can be reflected by the different levels of grain yields for each crop in the areas where it is grown. Yields are high in the areas where natural conditions are most suitable for the production, and low in the areas where the natural conditions are not so favourable. Map 5.2, Map 5.3 and Map 5.4 demonstrate the spatial distributions of respective grain yields. To reduce the effect of random factors and to enhance the significance of important producing provinces for each grain crop, provinces whose sown area of a respective grain crop is less than 4 percent are ignored in the analysis. The remaining provinces are arbitrarily divided into two categories, taking 20 percent as the norm for rice and wheat, and 15 percent for corn. Provinces with sown areas above the norm are defined as major producing provinces for the corresponding crops, and those below the norm are non-major producing provinces.

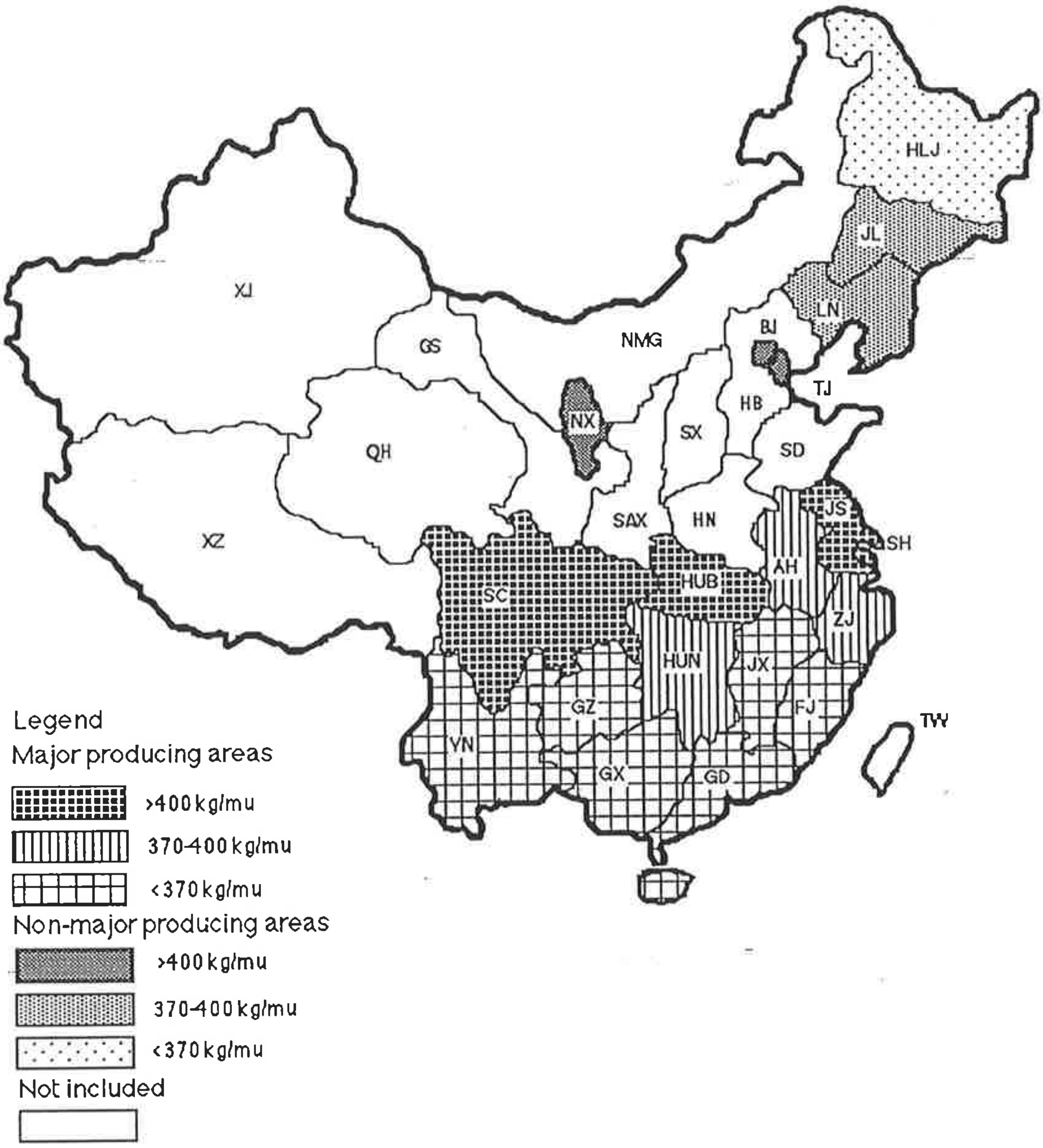
In China's statistics, rice is divided into northern rice and southern rice according to the location of production. Northern rice refers to rice grown north of the Qinling Mountain and Huaihe River, a dividing line which runs through southern Shaanxi and Henan, northern Anhui and Jiangsu. South of this line is southern rice.

It is necessary to point out that northern rice is Japonica rice (*gengmi*). In southern China, Indica rice (*xianmi*) is dominant and Japonica rice is only produced in a few of the provinces along the Yangzi River, including Jiangsu, Shanghai, Anhui, Hubei, and Yunnan. The proportion of the Japonica sown area in the total rice sown areas of these provinces is generally small. The data in the SPB household survey shows that per unit area inputs and yields for the two types of rice are slightly different, with a higher level for Japonica rice. The price of Japonica rice is generally higher than Indica rice because of the larger demand for Japonica rice. It would therefore be more appropriate to separate these two major rice varieties in this study. However, in official statistics, there are few data for sown areas and output of Japonica rice in southern provinces. This prevents the separate analysis of these two varieties. Nevertheless, Japonica rice accounts for a relatively small proportion of total rice production. In the 14 northern rice (Japonica) producing provinces, the output of rice in 1990 was 16.232 mmt, 18.1 percent of the total national rice output. This relatively small proportion means that any distortion created by treating rice in aggregate in this analysis will be small. The difference needs to be born in mind, however, when comparing the results for the northern and southern provinces.

In 1989/90, the average yield of rice at the national level was 374 kg/mu (SSB, *ZTN*, 1991). As shown in Map 5.2, the provinces above average are mainly located in the middle and lower reaches of the Yangzi River, including Sichuan, Hubei, Hunan, Anhui, Jiangsu, Zhejiang and Shanghai. South of the Yangzi River, in Fujian, Jiangxi, Guangdong, Guangxi, Guizhou and Yunnan, rice yields are relatively low. Rice production is not important in northern China, though the yields are generally high.

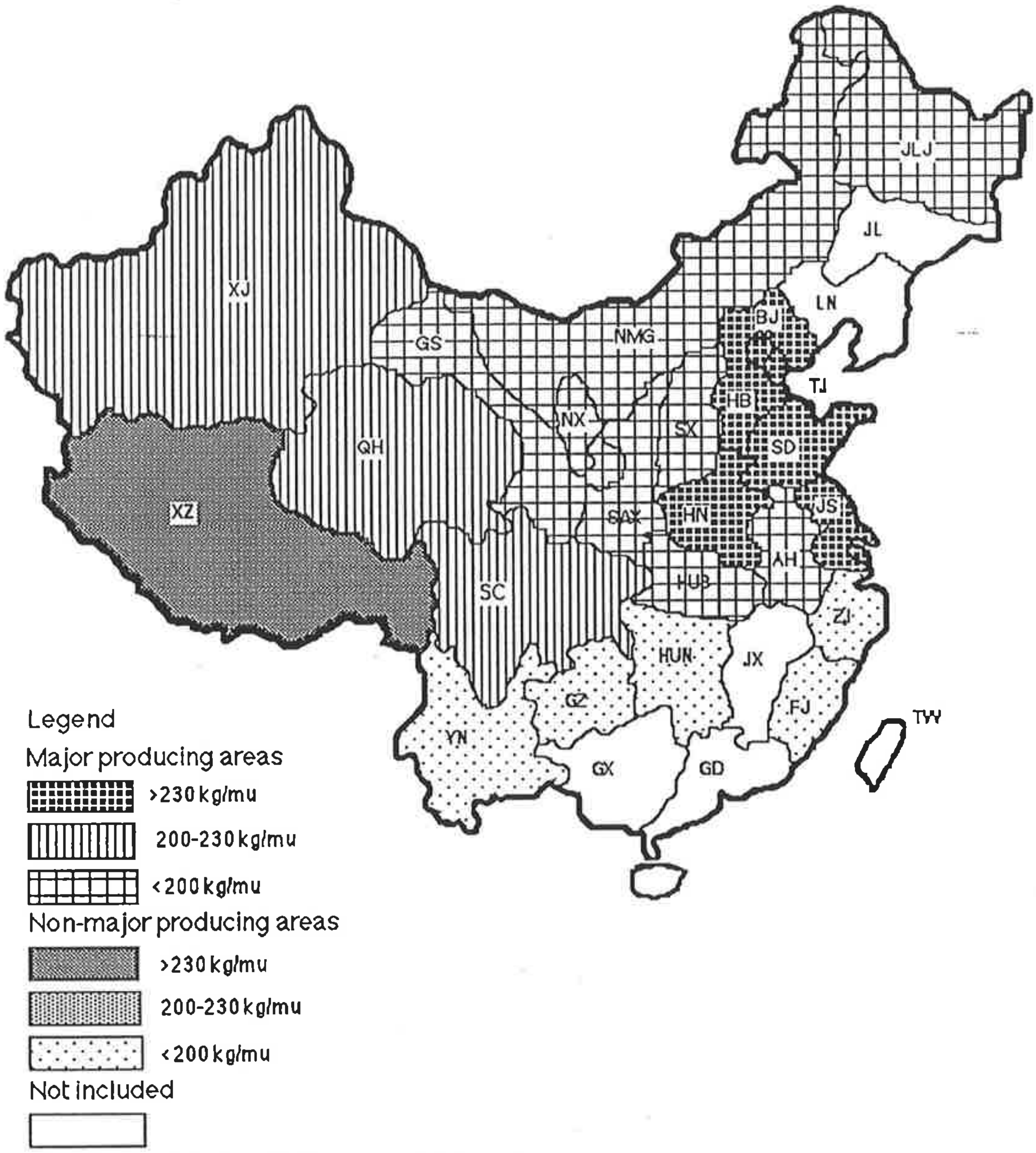
The different yields among provinces reflect, to a certain extent, the influences of natural conditions. Serious damage caused by insects is one of the reasons for the low yield south of the Yangzi River (Liu Zhicheng, et al, 1989). The topographical features in this area are also responsible. Hills and terraces predominate. The ecological conditions for rice production are therefore not as favourable as in the middle and lower reaches of the Yangzi River, where flat cultivated land and fertile soil have resulted in prosperous agriculture and higher rice yields. The relatively high yields of northern rice can partly be explained by the intensive material inputs utilised in the limited areas where natural conditions are suitable for Japonica production. For

Map 5.2. Rice Yield for Different Provinces, 1989/90



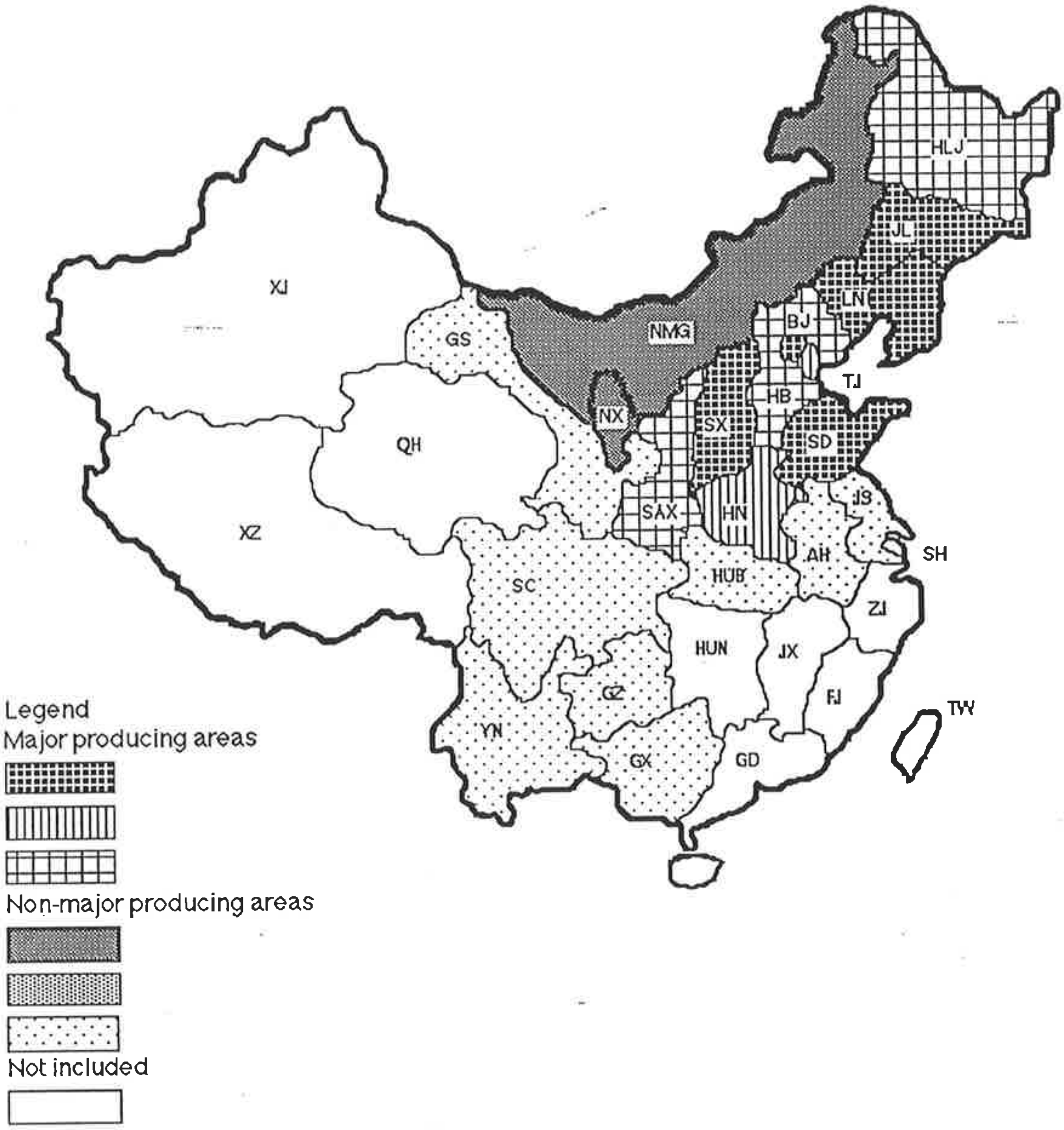
* Average rice yield was 374kg/mu in 1989/90.
Source: SSB, ZNTN, 1991, p.113.

Map 5.3 Wheat Yield for Different Provinces, 1989/1990



• Average wheat yield was 208 kg/mu in 1989/90.
Source: SSB, ZNTN, 1991, p.114.

Map 5.4 Corn Yield for Different Provinces, 1989/1990



* Average yield of corn was 281 kg/mu in 1989/90.
Source: SSB, ZNTN, 1991, p.114.

example, in Beijing and Ningxia material inputs exceeded 110 yuan/mu in 1990, whereas the national average was 90 yuan/mu (SPB, *QNCSZH*, 1991). In Ningxia, the rice yield reached 603 kg/mu in 1990 (SSB, *ZTN*, 1991), the highest yield among the provinces. This high rice yield has, however, long been recognised to benefit from the fertile soil and a developed irrigation system in the Hetao Plain.[14]

Wheat production is distributed widely in China. As shown in Map 5.3, however, the major producing areas are concentrated north of the Yangzi River. There are two regions where wheat yields are high. One is in the Huabei Plain, including Beijing, Tianjin, Hebei, Shandong and Henan, and the adjacent province of Jiangsu. Another is in the west, including Qinghai and Xinjiang, as well as Sichuan province. Scientific research has found that the higher wheat yield in Qinghai and Xinjiang benefit primarily from the long period of sunshine during the growing season (Liu Zhicheng, ed, 1989).

Corn production is concentrated in the far north of China, as shown in Map 5.4. In 1989/90, the national average of corn yield was 281 kg/mu. In the northeast part of China, including Liaoning, Jilin, Shandong and Hebei, corn yield was generally higher than elsewhere. Once again, this indicates the favourable natural conditions for corn production.

The above features indicate that the spatial patterns of provincial grain production and the levels of grain yields are strongly influenced by natural conditions in the provinces. For the respective grain crops, the major provinces usually have a higher yield than the non-major provinces. This is particularly the case for wheat and corn. The impact of natural conditions

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14 "Huanghe baihai, fu yu yitao" (The Yellow River causes a hundred troubles except for the Hetao Plain) is a well known proverb.

means that given a certain level of inputs, output could be different. Comparative studies of provincial grain production must therefore take the effects of natural conditions and the variations of the grain production structure into consideration.

5.4 The Growth Patterns of Disaggregate Provincial Grain Yields

As shown in Table 5.6, between 1978 and 1990, yields of rice, wheat and corn increased in all provinces. This is consistent with the situation at the national level. However, variations are significant among provinces and individual grain varieties. Several notable features can be seen in Table 5.6.

Firstly, for respective grain crops, large increases were concentrated in the major producing provinces. This is particularly so for wheat and corn. For example, the large increase in wheat yields occurred in Beijing, Tianjin, Hebei, Shandong, Henan, Shanxi and Anhui. Corn yields increased remarkably in Hebei, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Jiangsu, Anhui and Sichuan. Bearing in mind that the highest yields of each grain crop are also concentrated in the major producing provinces, it may be argued that a structural adjustment towards more specialised grain production in individual provinces will increase production efficiency. Further discussion of this point is presented in Chapter 9.

As for rice, although the major producing provinces generally had large increases, some non-major producing provinces in the north also increased remarkably. One of the reasons, as mentioned previously, is because northern rice is only produced in limited areas where local conditions are suitable for rice production. Another reason is the increasing demand for

Table 5.6 Growth Patterns of Yield of Respective Grain Crops for Different Provinces, 1978-1990*

(kg/mu)

Area	Rice			Wheat			Corn		
	I & II**	I	II	I & II	I	II	I & II	I	II
Country	117	93	32	90	75	17	115	77	61
Beijing	103	74	38	133	24	104	153	71	62
Tianjin	186	147	37	143	-18	102	189	122	36
Hebei	85	53	5	107	61	36	117	81	12
Shanxi				132	122	16	92	30	39
Neimenggu				106	58	44	114	-12	94
Liaoning	89	147	88				120	117	141
Jilin	173	159	82				255	191	145
Heilongjiang	90	77	33	83	33	54	102	15	136
Shanghai	96	24	85	2	10	-1			
Jiangsu	143	143	15	74	86	2	149	138	18
Zhejiang	53	86	-9	33	34	5			
Anhui	132	95	24	85	102	-15	127	78	40
Fujian	83	68	14	57	45	17			
Jiangxi	108	86	20						
Shandong	228	96	113	115	81	7	117	129	9
Henan	106	55	63	79	97	6	109	44	79
Hubei	175	121	40	58	47	20	41	39	5
Hunan	101	90	10						
Guangdong	120	86	49						
Guangxi	105	57	49				41	30	21
Sichuan	164	123	59	64	72	-3	107	78	36
Guizhou	41	65	45	50	33	25	11	37	19
Yunnan	72	32	36	34	34	27	16	17	7
Xizang				67	11	59			
Shaanxi	80	49	44	79	73	16	37	40	13
Gansu				57	40	26	32	-28	30
Qinghai				59	33	21			
Ningxia	208	153	42	63	56	31	104	13	61
Xinjiang	169	84	68	132	61	57	159	63	81

* Figures for the grain crops whose sown areas are smaller than 4 percent of the provincial total grain sown areas are not presented in this table.
** Period I refers to 1978-1984. Period II refers to 1985-1990.

Source: USDA, *ERS*.

Japonica rice, which generally has a higher quality. Both the state purchase prices and the market prices for northern rice were higher than for southern rice (SSB, *QNCSZH*, 1981-1991).

Secondly, in accordance with the changes in grain yields at the national level, provincial disaggregated grain yields generally experienced two sub-periods, before 1985 and after 1985. Table 5.6 shows that in most provinces, the yields of rice, wheat and corn increased rapidly during the first sub-period and slowed down in the second sub-period. This feature is more apparent in many major producing provinces. For rice, this can be seen in Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Hunan, Hubei and Sichuan. For wheat, it was in Hebei, Shanxi, Jiangsu, Anhui, Shandong, Henan and Hubei. For corn, this can be seen in Hebei, Jiangsu, Anhui, Shandong, Sichuan and Shaanxi. Since these provinces are the most important producing provinces for the respective grain crops in China, the slow increases after 1985 were largely responsible for the stagnation in the yields of respective grain crops at the national level. However, it is also noteworthy that in some major corn producing provinces, such as Liaoning, Jilin, Heilongjiang and Henan, the increase in corn yield was significant during the second sub-period, which implies a relatively better performance of overall corn production during this period. In many non-major wheat and corn producing provinces, yields increased slowly during the first sub-period, and maintained a relatively stable growth during the second sub-period. As mentioned in Chapter 4, however, the contribution of these provinces to national grain production is far less significant compared with the major provinces due to their small shares in the national total.

While recognising the effect of natural conditions on the spatial distribution and growth patterns of provincial grain yields, the effect of socio-economic factors on provincial grain production cannot be ignored. Observing the growth patterns of grain yields in the two sub-periods, it can be seen that the provinces where grain yields increased greatly during the first sub-period were those major producing provinces where the rural economies are developed and natural conditions are favourable. In other major producing provinces where the rural economies developed slowly and natural conditions are relatively poor, yields increased relatively little. However, in the second sub-period, the situation was more or less reversed. Grain yields increased slowly in the provinces where the rural economy developed rapidly. In the provinces where the rural economy developed relatively slowly, grain yields continued to increase, though the pace was slower than during the first sub-period. This suggests that the different levels of rural economic development had an effect on the growth patterns of provincial grain yields. The discussion of this issue needs to be integrated into the analysis of the changes in total factor productivity of provincial grain production and the causes of the changes during the period studied. This analysis will be undertaken in Chapter 7 and Chapter 8.

5.5 Conclusion and Implications

Between 1978 and 1990, grain yields increased remarkably. Against this broad background, however, the growth of yields was uneven over time for respective grain crops and in different provinces. This contributed to the unevenness in grain output during the same period.

Generally speaking, the reforms in the rural organisational system provided incentives for grain production in the early 1980s. This became the major catalyst of the rapid increase in grain yields during this period, when material inputs increased only a little, whereas labour inputs decreased dramatically. After 1985, the increase in grain yield was modest, although material inputs increased to a large extent. Poor weather conditions were partly responsible for this slow increase. However, another direct reason was the transition of grain production from relying on the accumulation of the previous period to being more dependent on a new set of inputs. Improving agricultural technology thus became crucial for sustaining growth in grain production.

This Chapter has also stressed that the spatial distribution of grain crops is responsible to a large extent for the disparities among provincial aggregate grain yields. Taking into consideration that the spatial distribution of grain production is dominated by natural conditions, caution is required when studying provincial grain productivity, in particular, when making comparisons among provinces.

In examining the growth pattern of provincial grain yields, it was found that the high levels and the large increases for respective grain crops occurred mainly in the major producing provinces for the corresponding crops. The non-major provinces generally had low yields and increased slowly. This feature implies an efficiency of specialisation in provincial grain production.

Two sub-periods of changes in grain yields can also be identified in most provinces and the trend appears related to the levels of rural economic development. In many major producing provinces where the rural economy is developed, a large increase occurred during the first sub-period and a modest increase during the second sub-period. Conversely, in the northwest provinces, where the rural economy is less developed, grain yields increased relatively slowly during the first sub-period but continued to increase in the second sub-period. This feature suggests that the different stages of development of the rural economy have had an influence on the growth patterns of grain yields.

The above analysis of changes in grain yields provides further insights into the factors affected grain production during the reform period. The questions remaining are whether or not the increases in grain yields were productively efficient, and what was the relationship between changes in yield and changes in total factor productivity among provinces for respective grain crops. These issues will be examined in the succeeding chapters.

Appendix 5.A Measurement of The Effects of Grain Production Structures on Provincial Aggregate Grain Yields

To estimate the extent to which grain production structures, which are dominated primarily by natural conditions, have influenced provincial grain yield, a linear regression model is established. The proportions of sown areas of rice, wheat, corn and soybean in the provincial total grain sown area are taken as independent variables and the aggregate grain yield as the dependent variable.[15] The data used are for 1990 from SSB, *ZNTN*, 1991. The result using OLS estimation is reported below:

$$Y = \underset{(0.151)}{9.489} + \underset{(4.950)}{3.688X_1} + \underset{(2.713)}{2.616X_2} + \underset{(4.272)}{3.870X_3} - \underset{(-0.272)}{0.455X_4}$$

where Y = aggregate grain yield measured by kilogram per mu;

X_1 = percentage of rice sown area in total provincial grain sown area;

X_2 = percentage of wheat sown area in total provincial grain sown area;

X_3 = percentage of corn sown area in total provincial grain sown area;

X_4 = percentage of soybean sown area in total provincial grain sown area;

Figures in parentheses are the T-ratios. The coefficient of determination $R^2 = 0.640$, D-W = 1.553 and F=10.222.

The result of the regression shows that the value of R^2 is 0.64. This means that approximately 64 percent of the disparities among provincial grain yields can be explained by the different proportions of sown areas of rice, wheat, corn and soybean in each province. The larger coefficients of rice

[15] Soybean is one of the most important miscellaneous grain crops.

and corn suggest that the level of provincial grain yield is strongly influenced by the proportions of sown areas of these two crops. The smaller coefficient of wheat indicates a less significant effect of wheat sown area on provincial grain yield. The negative coefficient of soybean, however, suggests that, given the total sown area in a province, increasing the sown area of soybean would lower the provincial average grain yield. Noting the insignificant T-ratio, the reliability of the coefficient of soybean may be poor. Nevertheless, considering the lower yield of soybean, which was 97 kg/mu in 1990 (SSB, *ZNTN*, 1991), the negative sign of the coefficient of soybean is reasonable.

It should be pointed out, however, that due to the crudeness of the data, the simplicity of the method used and the possibly high degree of multicollinearity in the estimation, the above coefficients should be treated as approximate estimates and should not be used as exact measures for further analysis.

Chapter 6

Estimation of Grain Production Functions and Analysis of the Parameters

6.1 Introduction

In measuring total factor productivity, the most important step is to determine the weight of each input. The task of this chapter is to estimate these weights using the production function approach outlined in Chapter 2. In addition, it will devote a great deal of effort to analysing the economic implications of each parameter estimated from the production functions.

There are different functional forms in production function analysis, so it is essential to determine one which is most appropriate for empirical studies. Before the estimated results can be used to make any conclusive judgement, it is also necessary to test the validity of the results. With this in mind, therefore, this study provides extensive discussion of the data issue, the choice of production function, the determination of the independent variables, the testing of the results and the interpretation of the economic implications of the results.

As shown in Chapter 5, the variations in grain types are an important reason for the difference in aggregate yields among the provinces. Since the yields of individual grain crops are closely related to their genetic characteristics, production functions will be different for each grain crop.

Therefore, production functions for wheat, rice and corn, are estimated separately in this chapter.

The chapter is organised as follows: Section 2 clarifies the data to be used in the estimation. It attempts to avoid the confusion caused by unclear definitions of data and to make the analysis as precise as possible. Section 3 specifies the functional forms for estimating grain production functions. Estimating and testing the results are undertaken in Section 4. Section 5 analyses the estimation results and compares the differences between estimates of the production functions for wheat, rice and corn. Some economic implications for the further development of grain production will be explored. This is followed by a summary of the main conclusions of the chapter in Section 6.

6.2 Data Specification

In studies of Chinese grain production, data insufficiency, inaccuracy and inconsistency have always presented problems. Although grain production has long been considered as one of the most important sectors in the national economy, official statistical data for grain production inputs are generally insufficient. Although during the 1980s, the issue of productivity received increasing attention, the lack of historical and empirical data for inputs still imposes constraints on the study of productivity in grain production. Nevertheless, with the increasing concern for the efficiency in grain production, a number of data sets for grain production inputs and outputs have been collected by different organisations, based on household surveys carried out in the last 10 or so years (see for example, You Jingwen, et al, 1990; the State Price Bureau (SPB), *QNCSZH*, 1981-1991; the Ministry of Agriculture (ECCAY), *ZNN*, 1984-1991; Zhao Shudong, et al, 1991; Zhang

Yimin, 1990; the State Council, 1990; Geng Dechang, 1990; and Zhou Zhangyue, 1992). The coverage of these surveys ranges from villages, to provinces, to the whole country. The availability of this household survey data has made it more feasible to use a production function analysis to examine the changes in total factor productivity of grain production.

6.2.1 Choice of the Data Set

A common feature of the above household surveys is that they are wide in cross-section, but relatively short in time series. The longest nationwide data set has been collected by the Ministry of Agriculture. This started in 1978 and covers all 30 provinces, autonomous regions and municipalities. Most of the other survey data sets have been collected after the mid 1980s. An exception is the household agricultural production survey organised by the State Price Bureau in co-operation with other departments. This survey has nationwide coverage and a relatively large number of observations. The survey started in 1981 and so far, the data from 1981 to 1990 are available.

In the previous studies of productivity for nationwide grain production, the data set most commonly used has been the one from the Ministry of Agriculture.[1] One of the reasons for using this set of data is that it has a relatively long time series, and since 1984 it has been published in the *Chinese Agricultural Yearbook* (ECCAY, *ZNN*). This has made the data more easily available. In contrast, although the data collected by the State Price Bureau (SPB, *QNCSZH*) also cover a relatively long time period, they were published as individual compendiums and were narrowly distributed. This

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[1] For instance, these data were used by Tian Weiming (1987), Jin Hehui (1990), Liu Zhicheng (1990) and Zhu Xigang (1991).

set of data was therefore much less available to the public than the data from the Ministry of Agriculture. This has constrained the use of the State Price Bureau data in previous studies.

Compared with the data set collected by the Ministry of Agriculture, however, the State Price Bureau data have two distinct advantages.

First, the number of households and the acreage covered in the State Price Bureau survey sample are larger than the one from the Ministry of Agriculture. On average, the sample size of the former is roughly three times that of the latter. For example, in 1986, the survey sample for wheat contained 4,878 households and covered 97,227 mu sown area in the data set of the State Price Bureau, but only 1,592 households and 10,986 mu in the one from the Ministry of Agriculture. As a larger sample of data can reduce the random effects on estimations, using the State Price Bureau data in estimating the production function can be expected to provide a better result.[2] Appendix 6.A provides the details of the numbers of households and the amount of sown areas surveyed for each grain crop in the two data sets.

Second, compared with data from the Ministry of Agriculture, more detailed information on inputs has been recorded in the data set from the State Price Bureau (See Appendix 6.A for a list of the items surveyed in the two data sets). In addition, figures for the inputs of chemical fertiliser, draught animals and seeds are recorded in both monetary and physical terms. This, to some extent, provides information for detecting possible errors in the

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[2] Both data sets, however, only provide provincial average figures for each household in terms of yield and various inputs. These figures were calculated based on the number of households and acreage surveyed in each province and in each year. Data for individual households within provinces are not presented. In the estimation of production functions in this study, therefore, data used are the provincial average for each household instead of all the individual households in all provinces.

data. In the data set from the Ministry of Agriculture, these figures are only given in monetary terms. Better still, in the production function analysis, using the physical terms of inputs can avoid the need to use price indices to convert inputs into constant prices based on a certain year. This is significant in studying the Chinese economy as the factor markets and prices are both distorted. Moreover, since 1985 the marketing reforms have allowed different agents to handle producer goods. The prices farmers have paid in purchasing these goods vary significantly depending on markets and regions. The price indices have therefore become less reliable as a means to measure the actual price paid by individual farmers for producer goods, although in many cases, they have to be used due to the lack of any better available choice.[3]

The merits of the data set from the State Price Bureau make it more appropriate to be used to estimate the production function in this study. However, because the data are only available since 1981, the situation in the years 1978-81 cannot be observed directly. Nevertheless, it may be argued that although the reforms started at the end of 1978, the effects on grain production did not become significant nationwide until the early 1980s. Since this study is mainly interested in the effect of rural reforms on changes in productivity, the absence of the data before 1981 is not a crucial problem.

6.2.2 The Measurement of Labour Input

One of the prominent characteristics of the household survey is that the figures for labour input are recorded as the actual input of standard labour hours or standard labour days. As discussed in Chapter 5, a standard labour is defined as an adult male labourer working at a medium labour intensity.

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3 Discussion of the effect of the quality of chemical fertiliser on the analysis of total factor productivity is presented in section 6.2.3.

His eight hours' work is regarded as a standard labour day. There are several merits in using this measurement. As applied in the survey it only measures the amount of labour used for grain production alone. The problem caused by farmers' involvement in multiple activities and the distortion of markets and prices in estimating the labour input can be avoided. This is particularly useful in the study of grain production, because of the large number of surplus labourers in this sector. Moreover, the measurement also avoids, to a certain extent, the problems caused by changes in labour characteristics in grain production. It has been reported that in many areas, mature and strong male labourers in grain production have tended to be replaced by the aged, children and female labourers (Zhao Shudong, et al, 1991; He Zhuowei, 1993). In the standard labour day measurement, labour provided by different age groups and genders is converted into standard labour day equivalents.

Despite the merits, some shortcomings of this measurement also need to be noted. An obvious one is that the concept "standard" is more or less vague and arbitrary. In grain production, there are many different types of work such as ploughing, sowing, weeding, spreading fertiliser, harvesting, threshing, storing and so forth. Different kinds of work tend to be undertaken by different groups of labourers. Generally speaking, male labourers undertake relatively heavy work such as ploughing, whereas female labourers are more concentrated in meticulous work such as weeding.[4] Therefore, converting the different groups of labourers into "standard" labour equivalents can only be done arbitrarily. Apart from this, the quality of labour in different groups, such as their educational and skill levels, cannot be distinguished by this measurement.

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[4] This is author's experience when working in the countryside in 1975 and 1976. The literature on Chinese agriculture has also recorded this feature, see for example, Buck (1937) and Tang Chi-Yu (1980).

Compared with the value share approach in estimating labour input in individual sectors as used in many previous studies reviewed in Chapter 2, however, the standard labour day is a better measurement for calculating the actual labour input in grain production. This measurement is, therefore, used in the following estimation of production functions.

6.2.3 Land, Chemical Fertiliser and Other Capital Inputs

The SPB survey was based on production teams in 1981, 1982 and 1983. Thereafter, it was based on individual households. In this study, for each grain crop the average land input of each household in a province is calculated by dividing the total provincial sown area surveyed by the number of households surveyed. To keep the data for the land input consistent in the production function analysis, the data for these three years are adjusted to the household level based on the average number of households in production teams in each province, which is available in the SSB, *ZTN*, 1983, p.148. As the land input is derived from the household survey, and the measurement of the land area is standard in the survey within a province and across different provinces, the problem in productivity analysis caused by the inaccurate data for China's overall arable land statistics can be avoided to some extent.

Chemical fertiliser is one of the important inputs in grain production and many studies have found that during the reform period, increasing use of chemical fertiliser has contributed significantly to the growth of grain output (Stavis, 1991; Research Institute of the State Price Bureau, 1992; Zhu Xigang and Shi Zhaolin, 1993; Zhou Zhangyue, 1993). It is therefore useful to take this input as an independent variable in estimating the production function. By doing so, the role of chemical fertiliser in the growth of grain output can be observed explicitly. In the SPB survey data, chemical fertiliser input is measured in both physical and monetary terms. To avoid the possible problem in converting the figures from the current price to the constant price, this study uses the physical terms in estimating production functions.

It is, however, worth noting that the data used for chemical fertiliser do not provide information about the combination of different types of fertiliser, such as N, P, and K. Empirical evidence has demonstrated that the different combinations can influence the effectiveness of chemical fertiliser as a whole in increasing output. Since no better options are available, this study will have to accept this unavoidable shortcoming. In additions, the chemical fertiliser in the SPB survey did not distinguish the varying quality of fertiliser. If the heterogeneity among different types of fertiliser is strong, it will affect the estimation of the production function. However, compared with the value term measurement, the physical term is still superior.

Other capital inputs in the survey were divided into two groups: direct and indirect inputs. The former refers to the inputs of seeds, pesticide, organic fertiliser, draught animals, irrigation, plastic film and machinery. The indirect capital inputs include the depreciation of fixed capital, costs for purchasing agricultural tools and field monitoring. The indirect costs are generally small and account for about 4-8 percent of the total production costs. In this study, direct capital inputs and indirect inputs are combined, and they are classified as "other capital input" to distinguish them from the chemical fertiliser input. Certainly, aggregating all other capital inputs into one category will lead to a loss of information about the effect of each input on output. However, attempts to separate these inputs in the regression failed due to serious multicollinearity problems. The aggregation of all other capital inputs is thus a compromise selection. In the estimation, the figures for other capital inputs were adjusted to 1978 constant prices by using the price index of producer goods from the SSB, *ZTN*, 1982-1991. Again, this adjustment was made in the absence of any better options.

6.2.4 The Variable for Weather Fluctuations

Grain production is influenced by various natural factors. The fluctuation in weather conditions is one of these factors, and it can affect significantly the output for the given level of inputs. As shown in Figure 5.2, there is an *inverse* relationship between the areas affected by natural disasters and grain output. Therefore, it is necessary to consider the weather factor in the estimation of the production function. Few previous studies, however, have included this factor. One of the reasons is, perhaps, the lack of data reflecting the effects of weather fluctuations. Another reason is that there are no common and sophisticated methods to monitor the effects of weather conditions. Zhang and Carter (1993) used the aridity index, which is calculated on the basis of monthly rainfall and temperature. The merit of this index is that it considers rainfall and temperature jointly, which gives more emphasis to the weather conditions in growing seasons. The constraint of this index is, however, also obvious. It requires monthly rainfall and temperature data for different areas and involves extensive data processing. Compared with Zhang and Carter, Nguyen and Wu (1993) used a simpler method. They took the percentage of areas affected by natural disasters in total crop sown areas as a proxy of weather conditions and accommodated this index in the regression as an independent variable. In Chinese statistics, natural disasters refer to flood, drought, frost, typhoons and hailstorms. Areas affected by natural disasters are defined as the areas where the crop output was reduced by more than 30 percent compared with normal years due to disasters. This study applies the same method as used by Nguyen and Wu mainly because of the limitations on the availability of data.[5]

The data for areas affected by natural disasters for individual provinces in 1980 and after 1983 are available from the SSB, *ZNTN*, 1985-1991. However, data for 1981 and 1982 are not available in any officially published statistics. In the following estimation of production functions, the figure for the ratio of areas affected by natural disasters to the total provincial crop sown areas for 1981 and 1982 is the mean provincial value for the years 1980, and 1983-1992. The detail of the calculation is presented in Appendix 6.B. As shown in Figure 5.2, the national weather conditions in these two years were normal. Using the mean value would, therefore, not significantly bias the estimation results.

6.3 Specification of the Model for Estimating Grain Production Functions

As elaborated in Chapter 2, there are different forms of production function. Choosing the appropriate functional form is essential for correctly stating the changes in total factor productivity and for conducting an economically meaningful analysis.

Because of the flexibility of the Translog production functional form and its relationship to the Cobb-Douglas production function, the former has been often used in empirical studies. In this study, the Translog form was considered at the initial stage. However, several trial regressions using the

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[5] An alternative way to monitor the effect of weather fluctuations on the production function is to subtract the areas affected by natural disasters from the total grain sown areas, and then to consider the areas affected by natural disasters as an independent variable in the regression. However, this method may cause a biased estimation, as the effects of weather fluctuations may also affect the performance of other inputs, including, fertiliser, labour, and other direct capital inputs. For this reason, it is more efficient to use the Nguyen and Wu's method to monitor the aggregated effects of weather fluctuations on grain production.

Translog forms for wheat, rice and corn failed to obtain statistically significant estimates due to serious multicollinearity problems in the regressions. This study, therefore, uses the Cobb-Douglas production function form in the estimation.[6] Experience has shown that simple functions involving as few parameters as is practically feasible often perform best. They can avoid the convergence problems in the estimation process occurring when there are a large number of independent variables in the estimated equation (Dawson and Lingard, 1989, Fan Shenggen, 1990).

As discussed in Chapter 2, in many previous studies using the Cobb-Douglas production function, a time trend is included in the regression to capture the neutral changes in technology. However, this measurement may have some shortcomings in studying Chinese agricultural production. In China due to the limit on land resources, technical progress is strongly biased towards land-saving. This means that technical progress may not be neutral over time. Even if the parameter for the time trend is insignificant in the regression, it does not mean that there is no technical progress, as biased technical progress is not necessarily insignificant. Therefore, including a time trend in the Cobb-Douglas production function for a relatively short period of time may not be much help in understanding technical progress in Chinese agricultural production. A trial regression using the SPB survey data did not show a statistically significant coefficient for the time trend. This is consistent with the results of the studies by Stavis (1991), Lin Yifu (1992), and Zhang Bin and Colin Carter (1993), in which the parameter of the time trend is not significantly different from zero. For this reason, it is more sensible to leave the time trend out and to concentrate on examining changes in total factor productivity from the ratios of outputs to inputs. This approach provides

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[6] Many scholars have used the Cobb-Douglas production function in estimating China's agricultural productivity. These include Feng Haifa, 1986; Tian Weiming, 1987; Zhu Xiguang, 1991; Stavis, 1991; Lin Yifu 1992; Zhang Bin and Colin Carter, 1993, and Wu Yanrui, 1993.

greater flexibility for the analysis of production movements and of relationships among variables.

In recent years, panel data analysis has been widely used in economic studies. This is because panel data can provide a rich environment for the development of estimating techniques and theoretical results (Greene, 1990). The major advantages of using panel data, as Hsiao (1986) pointed out, are: 1) the large number of data points, increasing the degrees of freedom and reducing the collinearity among explanatory variables, and 2) the capacity to analyse economic questions that cannot be addressed using cross-sectional or time-series data sets. Because of these advantages, this study uses a panel data approach to estimate production functions for wheat, rice and corn. The natural logarithm Cobb-Douglas functional form based on the discussion above and fitted with panel data can be written as:

Fixed:
$$Ln(Y_{it}) = d_i + a_1 Ln(S_{it}) + a_2 Ln(L_{it}) + a_3 Ln(F_{it}) + a_4 Ln(K_{it}) + a_5 Ln(D_{it}) + e_{it} \quad (6.1)$$

Random:
$$Ln(Y_{it}) = a_0 + a_1 Ln(S_{it}) + a_2 Ln(L_{it}) + a_3 Ln(F_{it}) + a_4 Ln(K_{it}) + a_5 Ln(D_{it}) + u_i + e_{it} \quad (6.2)$$

$$(i = 1, 2, \ldots, N; t = 1, 2, \ldots. T)$$

where Y = output measured in kilogram,

S = sown area measured in mu,

L = labour input measured in the standard labour days,

F = chemical fertiliser measured in kilogram,

K = other capital inputs measured in yuan.

D = weather index measured by the percentage of areas affected by natural disasters in total crop sown areas.

All the variables are the household level figures based on the provincial average given in the SPB survey. Form (6.1) and form (6.2) are, in turn, called the "fixed effects model" and the "random effects model" (Hsiao, 1986, Greene, 1990). d_i, a_0, a_1, a_2, a_3, a_4 and a_5 are parameters to be estimated. d_i in form (6.1) stands for the fixed effects of the i^{th} individual (or province in this context). a_0 in form (6.2) is the constant term, and u_i is the random disturbance characterising the i^{th} individual province and it is consistent through time. e_{it} is the residual. Subscripts i and t stand for the i^{th} individual province at year t.

In practice, the choice of whether to use the fixed effects model or the random effects model depends upon "the context of the data, the manner in which they were gathered, and the environment from which they came." (Hsiao, 1986, p.43). In previous studies of Chinese agricultural production function, models with random effects (form 6.2) have been used the most (Fan Shenggen, 1990; Zhu Xigang, 1991; Zhang Bin and Colin Carter, 1993). Aware of the effects of regional disparities in natural environment and socio-economic conditions on regional production, some scholars have adopted dummy variables in the random effects models to capture the specific effects of individual regions or provinces. However, there are some shortcomings in using regional dummies. One is that they are often set rather arbitrarily and within a region heterogeneous features are sometimes very strong (see Chapter 3 for the discussion). Apart from this problem, the random effects model with dummy variables is also costly in terms of degrees of freedom lost (Greene, 1990, p.495). This reduces the efficiency of estimates. Compared with the random effects model, the fixed effects model approach has advantages in terms of distinguishing the provincial specific effects and, at the same time allowing a more efficient estimation.

The basic idea underlying the fixed effects model is the belief that the differences between individuals can be viewed as parametric shifts of the regression function (Greene, 1990, p.485). In studying China's grain production, the characteristic of the fixed effects model is of significance, due to the existence of regional disparities in terms of grain production conditions. This is particularly important in this study, because it aims to explore the provincial disparities in total factor productivity and their relationships to provincial-specific effects. The different values of fixed effects among provinces reflect the impact of natural and socio-economic factors on the relative levels of productivity, which is an issue of central concern. Therefore, the fixed effects model is used in the following estimation.[7]

6.4 Report of the Estimation Results

For the reasons discussed above, the production functions for wheat, rice and corn are estimated separately. The estimations first concentrate on wheat. The procedures used for estimating the production function for wheat are also suitable for rice and corn. The computer program used was LIMDEP version 6.0 developed by William Greene (1991).

1) Wheat

The sample from the survey for estimating the production function for wheat includes 20 provinces, autonomous regions and municipalities. These,

[7] According to Hsiao (1986) and Greene (1990), the test of the suitability of the fixed effects model and the random effects model in a specific case is to examine whether d_i is correlated with explanator variables. A fixed effects model should be used when d_i is correlated with explanator variables, and a random effects model should be used when d_i is uncorrelated with explanator variables. For this study, the Wald test (or Hausman statistic) suggests that a fixed effects model is more appropriate.

in turn, are: Beijing(1), Tianjin(2), Hebei(3), Shanxi(4), Neimenggu(5), Heilongjiang(8), Shanghai(9), Jiangsu(10), Anhui(12), Shandong(15), Henan(16), Hubei(17), Sichuan(21), Guizhou(22), Yunnan(23), Shaanxi(24), Gansu(25), Qinghai(26), Ningxia(27) and Xinjiang(28). The other provinces are not included because of the small proportion of wheat sown areas in provincial total sown areas and/or the absence of data. The data are from 1981 to 1990, with a total 200 observations. Table 6.1 presents several regression results using the ordinary linear squares estimation (OLS).

Regression R1 uses the form (6.1) specified above. The result shows that the t-ratio of labour input is statistically insignificant. Examining the correlation among inputs, it is found that the labour input is correlated to land, fertiliser and other capital inputs. This correlation is understandable as experience tells that changes in labour input would be most likely to bring simultaneous changes in land, machinery and other inputs.

The statistically insignificant elasticity of labour input may also be related to the existence of surplus labour in grain production. As shown in Table 5.2, labour input decreased rapidly during the early years of the reforms and stabilised suddenly with the completion of the implementation of the HRS in 1984. It is argued that the stable level of labour input after 1985 may reflect the small marginal output of labour input. This implies that there are not enough variations to allow the regression to capture the effect of marginal changes in labour input on output. Therefore, the elasticity of labour input may not be able to be estimated in this case.

Table 6.1 Estimates of Production Functions for Wheat, 1981-1990

(Fixed effects model)

Coefficient	R1	R2	R3
Land	0.576	0.527	
	(4.621)	(5.670)	
Labour	- 0.034		
	(-0.589)		
Chemical fertiliser	0.180	0.190	0.189
	(4.327)	(5.011)	(5.033)
Capital	0.298	0.299	0.299
	(3.825)	(3.856)	(3.873)
Disaster	-0.038	-0.041	-0.041
	(-2.146)	(-2.275)	(-2.301)
R^2	0.989	0.987	0.837
F	545.710	572.221	321.092
Hausman statistic	15.351	17.243	11.602
Sum	1.020	1.015	
d1 = 4.080*	d8 = 3.794	d16 = 4.106	d24 = 4.043
d2 = 4.082	d9 = 4.209	d17 = 3.931	d25 = 4.036
d3 = 4.060	d10 = 4.174	d21 = 4.132	d26 = 4.009
d4 = 4.072	d12 = 4.022	d22 = 3.850	d27 = 3.986
d5 = 3.902	d15 = 4.127	d23 = 3.992	d28 = 3.974

* The d_i reported is from the regression R2. The order of the provinces is the same as presented in the text.

As the parameter value of labour input is fairly small and insignificant, this variable is omitted in the regression R2. (The effect of this omission on the analysis will be discussed in Section 6.5). The result shows that the elasticity of land input decreased significantly, the chemical fertiliser input increased slightly and the others have no significant changes. The coefficient of determination R^2 also changed slightly. The differences in the elasticity of land input in R1 and R2 reflects the correlation between land input and labour input.

In R1 and R2, the sum of the coefficients is approximately equal to one, suggesting constant returns to scale in wheat production. To test this, a hypothesis can be set as:

$$H_0: a_1 + a_3 + a_4 = 1$$

As the coefficient of labour input is insignificant, the test is based on the result of the regression R2. The value of a parameter of any of the input variables is represented by 1 minus the rest of the parameters. The coefficient of land input, therefore, can be specified as:

$$a_1 = 1 - a_3 - a_4$$

The form (6.1) then becomes:

$$Ln(Y_{it}) = d_i + (1 - a_3 - a_4)Ln(S_{it}) + \qquad (6.3)$$
$$+ a_3 Ln(F_{it}) + a_4 Ln(K_{it}) + a_5 Ln(D_{it}) + e_{it}$$

$$Ln(Y_{it}) - Ln(S_{it}) = d_i + a_3[Ln(F_{it}) - Ln(S_{it})] \qquad (6.4)$$
$$+ a_4[Ln(K_{it}) - Ln(S_{it})] + a_5 Ln(Dit) + e_{it}$$

$$Ln(Y_{it}/S_{it}) = d_i + a_3(Ln(F_{it}/S_{it}) \qquad (6.5)$$
$$+ a_4(Ln(K_{it}/S_{it}) + a_5 Ln(Dit) + e_{it}$$

The dependent variable on the left hand side of the form (6.5) becomes the yield, and the independent variables on the right hand side denote chemical fertiliser and other capital inputs per unit area, respectively. The variables are all in the logarithmic forms. Apart from testing the hypothesis of constant returns to scale, the form (6.5) is also of practical significance. Because of China's lack of arable land, the increase in grain output has mainly relied upon the increase in output per unit of land. The parameters in the form (6.5) indicate the elasticities of chemical fertiliser and other capital inputs to wheat yield.

R3 in Table 6.1 shows the estimated result of applying the form (6.5), which is on the basis of per unit area. The F test does not reject the hypothesis that there are constant returns to scale in wheat production (at the 5 percent level).[8] Therefore, constant returns to scale can be accepted for wheat production. This result suggests that an equiproportionate change in all the inputs will generate the same proportionate change in output.[9]

The fixed effect term d_i shows the variations in different provinces. Theoretically, the values of d_i reflect the relative levels of average productivity in different provinces under the given natural conditions and level of socio-economic development. Therefore, they can be used to judge the efficiency of provincial production in terms of resource utilisation. A high value of the fixed effect means that, given the level of inputs, the output is large. In contrast, a small value of the fixed effect means a small output under

8 Because the dependent variable in form (6.5) is different from that in form (6.1), the F test using the value of R^2 is no longer valid. In this case, the F test is processed by using the unrestricted sum of squared residuals and the restricted sum of squared residuals (Greene, 1990, p.216). The F value here is 0.087. The critical value in the F test table is 3.890 at the 5 percent significant level.

9 The result of constant returns to scale will be used in analysing the sources of yield growth in Chapter 7.

a given level of inputs. Further analysis of relative provincial efficiency in grain production will be presented in Chapter 9.

2) Rice

The estimation procedure for rice is basically the same as has been described for wheat. In the SPB survey, however, the data for rice are collected separately on the basis of different kinds of varieties. In the regression, the weighted average output and inputs of different kinds of rice are used to estimate production function of rice.[10] The sample includes 20 provinces and 200 observations. The provinces are Beijing(1), Tianjin(2), Liaoning(6), Jilin(7), Heilongjiang(8), Shanghai(9), Jiangsu(10), Zhejiang(11), Anhui(12), Fujian(13), Jiangxi(14), Henan(16), Hubei(17), Hunan(18), Guangdong(19), Guangxi(20), Sichuan(21), Guizhou(22), Yunnan(23) and Ningxia(27). Table 6.2 shows the results of the estimations.

Like the situation in wheat production, the coefficient of labour input is small and statistically insignificant for rice in the regression R1. In regression R2, the variable for labour input is dropped. The coefficients in R2 changed somewhat compared to that in R1, in particular for land input and the other capital input.

The sum of coefficients is approximately equal to 1 in R1 and R2. The regression R3 using the form (6.5) shows that the coefficients for different inputs changed slightly compared to R2. The F test does not reject the

[10] The author is aware of effects of the heterogeneity of different rice varieties on the estimation, in particular, the difference between Indica rice (*xianmi*) and Japonica rice (*gengmi*). However, separating estimations of production functions for different varieties of rice are constrained by the small numbers of provinces for each type of rice and the insufficient data in official statistics. Therefore, this study estimates only the aggregate rice production function.

hypothesis of constant returns to scale in rice production.[11] The constant returns to scale can be accepted.

Table 6.2 Estimates of Production Function for Rice, 1981-1990

(Fixed effects model)

Coefficient	R1	R2	R3
Land	0.643 (8.157)	0.658 (10.311)	
Labour	0.031 (0.562)		
Chemical fertiliser	0.115 (4.528)	0.119 (4.750)	0.119 (4.111)
Capital	0.208 (3.098)	0.258 (3.392)	0.222 (2.587)
Disaster	-0.045 (-2.624)	-0.039 (-2.580)	-0.041 (-2.581)
R^2	0.981	0.980	0.488
F	497.090	451.000	327.470
Hausman statistic	12.509	11.880	7.556
Sum	0.997	1.035	
d1 = 4.991*	d9 = 5.275	d14 = 5.013	d20 = 4.968
d2 = 5.029	d10 = 5.227	d16 = 5.185	d21 = 5.365
d6 = 5.255	d11 = 5.151	d17 = 5.096	d22 = 5.196
d7 = 5.180	d12 = 5.049	d18 = 5.195	d23 = 5.195
d8 = 5.024	d13 = 5.053	d19 = 4.909	d27 = 5.315

* The d_i reported is the result of R2.

3) Corn

The sample for corn production is from 19 provinces and 190 observations. They, in turn, are: Beijing(1), Tianjin(2), Hebei(3), Shanxi(4),

11 The F test for the hypothesis of constant returns to scale is 2.145. The critical value from the F table is 3.890 at the 5 percent level.

Neimenggu(5), Liaoning(6), Jilin(7), Heilongjiang(8), Jiangsu(10), Anhui(12), Shandong(15), Henan(16), Hubei(17), Sichuan(21), Guizhou(22), Yunnan(23), Shaanxi(24), Gansu(25) and Xinjiang(28). The estimates of production functions are reported in Table 6.3.

Table 6.3 Estimates of Production Function for Corn (1981-1990)

(Fixed effects model)

Coefficient	R1	R2	R3
Land	0.699 (8.451)	0.565 (8.530)	
Labour	-0.239 (-3.361)		
Chemical fertiliser	0.234 (8.478)	0.224 (7.839)	0.226 (7.860)
Capital	0.237 (5.237)	0.221 (4.725)	0.221 (4.675)
Disaster	-0.048 (-3.588)	-0.047 (-3.196)	-0.049 (-3.390)
R^2	0.989	0.985	0.858
F	810.380	784.122	37.670
Hausman statistic	9.228	11.470	8.520
Sum	0.972	1.010	
d1 = 4.900*	d6 = 4.972	d15 = 4.807	d23 = 4.496
d2 = 4.910	d7 = 5.014	d16 = 4.805	d24 = 4.744
d3 = 4.864	d8 = 4.803	d17 = 4.664	d25 = 4.738
d4 = 4.837	d10 = 4.829	d21 = 4.581	d28 = 4.883
d5 = 4.884	d12 = 4.723	d22 = 4.439	

* The d_i reported is the result of regression R2.

Regression R1 is estimated by using form (6.1). It can be seen that the coefficient of labour input of corn is negative. This is unlikely to be the case in reality. In the regression R2, the variable of labour input is dropped. The coefficient of land input decreases significantly, implying that there is a strong correlation between sown areas and labour input. The sum of coefficients in R2 is approximately equal to one.

Form (6.5) is used in regression R3 to test the pattern of returns to scale. The F test, again, does not reject the hypothesis of constant returns to scale in corn production at a 5 percent significant level.[12] Therefore, constant returns to scale is accepted.

6.5 Analysis of the Parameters and the Comparison of Production Functions for Wheat, Rice and Corn

In the above estimation of production functions of wheat, rice and corn, the most notable point is that the elasticity of labour input is either statistically insignificant or negative. This is contrary to the expectation of a statistically significant and positive elasticity of labour input. One of the reasons, as mentioned above, is because of the multicollinearity problem which makes it difficult to observe the separate elasticity of the labour input. This problem was also found in other previous studies of Chinese agricultural production, such as Nguyen and Wu (1993) and Tsang Shu-ki and Cheng Yuk-shing (1994). Although Stavis, (1991) did not mention this issue in his estimation of production function, the negative coefficient of labour input in that study is most likely caused partly by the same problem. In some other studies, such as Lin Yifu (1992), a statistically significant and positive coefficient of labour input was derived, the value was, however, relatively small. In Lin's estimation, it was only 0.13. Fan Shenggen's study (1990), using a Translog form of production function, shows that the elasticity of labour

[12] The F value in the test is 3.303 and the critical value in the F table is 3.92 at the 5 percent significance level

input decreased over time.[13] Despite some variations, the results of this study and the other studies mentioned above may imply a relatively small elasticity of labour input in Chinese agricultural production.

It should be pointed out that no matter whether the elasticity of labour input is small or not, the marginal productivity of labour input is most likely to be negligible in Chinese grain production. According to the definition, the marginal productivity of labour input is $\partial Q/\partial L=\varepsilon*Q/L$. ε stands for the output elasticity of labour input, Q is the output and L is the labour input. Given the elasticity ε, it is clear that with the increase in L, the marginal productivity of the labour input will decline, as the output Q cannot keep the same growth rate as labour input increases due to the effect of diminishing returns. When L reaches a certain level, the marginal productivity of labour input $\partial Q/\partial L$ will tend to be zero. The whole process can be accelerated when the ε is small. This is most likely the case in Chinese grain production. The existence of surplus labour may force farm households to increase labour input to the level where the marginal productivity of labour input is negligible or very low. In other words, increasing labour input beyond the current level has no significant effect on output.

The existence of surplus labour means that the labour supply has little limitation compared with other inputs. In this case, it is reasonable to believe that the level of grain output is determined primarily by other inputs. The omission of the labour input in the regression simply means that the effects of the labour input, if any, have been embraced in other inputs. The following analysis therefore will concentrate on the land, chemical fertiliser and other capital inputs.

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13 Lin and Fan used longer time series in their estimations, which may have helped to reduce the effects of the multicollinearity problem on the estimation.

A comparison between wheat, rice and corn shows that differences of parameter values are significant for respective inputs. It is also noted that for each grain crop, the values of the elasticity of respective inputs differ from the ones estimated for aggregate grains as reviewed in Chapter 2. These results indicate the differences between the production functions for the respective grain crops and underline the necessity to estimate them separately. From the standpoint of understanding the mechanism of the development of grain production, a disaggregate approach is obviously superior compared with an aggregate one, because the former provides more specific information about the input-output relationship for each crop. This information is of importance for stipulating appropriate policy measures for guiding grain production.

Table 6.4. Comparison of The Coefficients of Wheat, Rice, and Corn*

Coefficients	Wheat	Rice	Corn
Land	0.527	0.658	0.565
Chemical fertiliser	0.190	0.119	0.224
Capital	0.299	0.258	0.221
Disaster	-0.041	-0.039	-0.047
Average d_i**	4.1	5.1	4.7

* Using R2 in Table 6.1, Table 6.2 and Table 6.3.
** Arithmetic average of d_i in R2.

To provide a clear view, the coefficients of wheat, rice and corn estimated in the previous section are brought together in Table 6.4. It can be seen that the coefficients of land input are large for all the three grain crops. It is also noticed that these values are generally larger than most of the previous studies of Chinese agricultural production reviewed in Chapter 2. One of the reasons for this can be attributed to the different scope of the studies. Many previous studies were concerned with agricultural production as a whole, either in the broad perspective or in the narrow perspective. The larger coefficient in this study implies that grain production is more reliant on sown areas than agriculture as a whole. Another reason, however, may be related to the omission of the labour input in the regressions in this study, which possibly adds a part of the labour input effect to the land input. Nevertheless, the high elasticity of the land input found in this study indicates that sown areas are a crucial factor in determining grain output in China. It underlines that government control over grain sown areas through central and local plans have been an effective means to stabilise grain output. This result, however, also implies that the potential for further increases in grain output in China is low, as the arable land is extremely limited and the sown area of grain has been declining.

The comparison among the three grain crops shows that the coefficients of land input of wheat and corn are smaller than that for rice. The marginal output of land input for different grain crops can be calculated. Based on the SPB data for 1990, the marginal outputs of a one mu increase in land input for wheat, rice and corn are 112.2 kg/mu, 251.2 kg/mu and 170.4 kg/mu, respectively.

The coefficient of chemical fertiliser input is important for all three grain crops. The comparison among wheat, rice and corn shows that wheat and corn have slightly larger coefficients than rice. According to the SPB household survey data used in this study, in 1990, the average chemical fertiliser consumption per mu was 68.78 kg/mu for rice, 52.6 kg/mu for wheat and 50.5 kg/mu for corn. The average yields were 414.23 kg/mu for rice, 230.33 kg/mu for wheat and 358.29 kg/mu. Therefore, the marginal output of a one kilogram increase in the chemical fertiliser input for rice, wheat and corn are 0.716 kg, 0.831 kg and 1.589 kg, respectively. This suggests that increasing chemical fertiliser is relatively effective for corn compared to rice and wheat. Given the average prices of chemical fertiliser and grains, 0.63 yuan/kg and 0.72 yuan/kg, respectively in 1990 (SSB, *ZTN*, 1991, pp.262-263), it seems that for wheat and rice, there was little incentive for farmers to further increase the application of chemical fertiliser.

It is noticed that the elasticity of capital inputs are higher than most of the previous studies reviewed in Chapter 2. This, on the one hand, may reflect the fact that the level of capital input is relatively important for grain production. On the other hand, it may imply that solely considering machinery, irrigation and draught animal as was done in many previous studies, is unable to state the effects of overall capital inputs. The information incorporated from the SPB survey shows that seeds and pesticides have also been very important inputs in grain production.

There are, however, significant differences in the output elasticities of wheat, rice and corn with respect to other capital inputs. The marginal output of this input also varies among respective grain crops. According to the SPB survey data, in 1990 the marginal outputs of other capital inputs were 0.92 kg/yuan for wheat, 1.16 kg/yuan for rice and 1.16 kg/yuan for corn. Given the fact that grain sown areas are showing a tendency to decline, increasing capital inputs are essential for further increases in grain output. For the technical reasons specified previously, however, this study cannot provide further details of the effect of each individual capital input.

Observing the average values of the coefficient of the fixed effects term d_i, it can be seen that rice has a generally higher value, and this is followed by corn. Wheat has the lowest value. This feature is related to the fact that, because of the differences in biological characteristics, the average yield of wheat is genetically lower than the average yields of rice and corn. The inference is that it is inappropriate to compare the yield levels among provinces without taking the biological characteristics of yields into consideration.

The proportion of areas affected by natural disasters in total sown areas of crops is included in the model to reflect the effect of weather fluctuations on grain output. Not surprisingly, the result shows a significantly negative coefficient of weather conditions. This indicates that the fluctuations in weather conditions have significant effects on the output, in particular, on rice and corn. This result supports the argument made in Chapter 5 that the growth pattern of grain yield has been strongly influenced by weather fluctuations. The favourable weather conditions contributed to the rapid increase in grain output in the early 1980s and the unfavourable weather in the late 1980s was one of the reasons for the slow down of the growth during this period.

6.6 Summary and Remarks

In this chapter, production functions for wheat, rice and corn are separately estimated. The result shows that the output elasticity of wheat, rice and corn with respect to land input is large, underlining the importance of land input in grain output. Stabilising grain sown areas is crucial to ensure stable output.

The regression cannot obtain a statistically significant elasticity of labour input for wheat, rice and corn, despite the fact that, in reality, a positive elasticity of labour input is expected. The conclusion that can be made here is that because of the existence of surplus labour, increasing labour input beyond the present level will have little effect on the output, no matter whether the elasticity of labour input is statistically significant or not. As the labour supply is relatively unlimited, grain output is determined primarily by the level of other inputs. In the regressions, the effect of labour input on the output of wheat, rice, and corn, if any, is embraced by the elasticities of other inputs.

The output elasticities of chemical fertiliser and other capital inputs are important for all the three grain crops. This implies that the potential for increasing grain output in China largely relies on these two inputs, given the fact that the sown area is limited and is tending to decline.

The weather factor is included in the estimation. The coefficient of this variable is significant and negative for wheat, rice and corn. This result further supports the argument made in Chapter 5 that the fluctuations in weather conditions have influenced grain output during the period studied. This result also suggests that in studying productivity changes, the effects of weather conditions must be taken into consideration.

Appendix 6.A

1. The State Price Bureau's Survey

Table 6.A.1 Production Costs, Gross Returns and Labour Productivity

Items		Unit
Numbers of counties, villages and households surveyed		county/household
Acerage surveyed		mu
Per mu	Output	jin*
	Gross value	yuan
	Material costs	yuan
	Labour days	days
	Labour costs	yuan
	Total production costs	yuan
	Tax	yuan
	Net income**	yuan
	Profits***	yuan
Average purchase price per 50 kg product		yuan
Labour productivity		yuan/day
Non-production costs per mu		yuan/mu

* 1 jin = 1/2 kg.

** Net income refers to the returns after deducting production costs.

*** Profits refer to the remainder after deducting production and labour costs.

Table 6.A.2 Calculations for Material Costs

Items	Uint
Total material costs	yuan/mu
Direct production costs	yuan/mu
1. seeds	yuan/mu
2. fertiliser	yuan/mu
3. pesticides	yuan/mu
4. draught animals	yuan/mu
5. machinery	yuan/mu
6. irrigation	yuan/mu
7. others	yuan/mu
Indirect production costs	yuan/mu
1. fixed capital depreciation	yuan/mu
2. costs for purchasing and reparing small agricultural production tools	yuan/mu
3. field monitor	yuan/mu
4. sales costs	yuan/mu
Appendix	
1. draught animals	unit/mu
2. seeds	jin/mu
3. chemical fertiliser	jin/mu
4. costs for purchasing chemical fertiliser	yuan/mu

Table 6.A.3 The Sample Size of the SPB Survey for Wheat, Rice and Corn, 1981-1990

Year	Wheat Counties	Wheat Households*	Wheat Sown areas mu	Rice Counties	Rice Households	Rice Sown areas mu	Corn Counties	Corn Households	Corn Sown areas mu
1981	490	805	168967	640	984	134227	391	575	105691
1982	508	892	159251	682	1142	61159	391	614	79728
1983	527	774	180014	729	1092	105787	436	677	90167
1984	478	3353	65710	584	3081	16208	291	2418	21046
1985	571	3454	64735	614	3804	19531	468	3008	20589
1986	601	4878	97228	679	4602	18570	473	3154	22551
1987	604	4034	78585	591	3594	17286	512	3263	22314
1988	632	4100	45864	660	4360	21843	496	3324	22542
1989	549	4071	42519	607	4369	22134	501	3463	22993
1990	593	4601	45626	710	4770	21643	487	3478	28163

* Figures for 1981, 1982 and 1983 are based on production teams.

2. The Ministry of Agriculture' Survey

Table 6.A.4 Production Costs, Gross Returns and Profits

Items		Unit
Households surveyed		household
Acreage surveyed		mu
Per mu	Output	kg
	Gross value	yuan
	Material costs	yuan
	Labour days	days
	Labour costs	yuan
	Total costs	yuan
	Profits	yuan
Material costs		yuan/mu
1. seeds		yuan/mu
2. fertiliser		yuan/mu
3. field monitoring		yuan/mu
4. machinery		yuan/mu
5. draught animals		yuan/mu
6. irrigation		yuan/mu
7. other direct costs		yuan/mu
8. common costs		yuan/mu
9. management and others		yuan/mu

Table 6.A.5 The Sample Size of the Ministry of Agriculture's Survey for Wheat, Rice and Corn, 1984-1990*

Year	Wheat Households	Sown areas mu	Rice Households	Sown areas mu	Corn Households	Sown areas mu
1984	1180	7791	1088	6597	934	4359
1985	1853	10985	1074	6463	1308	5386
1986	1592	8985	1056	6396	1084	4757
1987	1891	12059	1175	6900	1456	6673
1988	1772	11004	1190	6788	1085	6037
1989	1670	10410	1816	10771	1087	5201
1990	1835	21049	1902	12657	1182	7112

* Data for 1981, 1982 and 1983 are not available.

Appendix 6.B

The Mean of Areas Affected by Natural Disasters and the Mean of Total Sown Areas,1980, 1983-1992

(10 thousand ha)

Provinces	Mean of areas affected by natural disasters	Mean of total crop sown areas	%
National	21860.76	145507	15.02
Beijing	69.36	616	11.26
Tianjin	98.82	600	16.47
Hebei	1621.70	8738	18.56
Shanxi	997.33	4061	24.56
Neimenggu	1207.39	4638	26.03
Liaoning	785.55	3705	21.20
Jilin	1011.97	4053	24.97
Heilongjiang	1394.33	8537	16.33
Shanghai	17.73	697	2.54
Jiangsu	1017.06	8487	11.98
Zhejian	379.73	4454	8.53
Anhui	1321.12	8087	16.34
Fujian	266.97	2545	10.49
Jiangxi	578.15	5537	10.44
Shandong	1665.97	10737	15.52
Henan	1630.00	11571	14.09
Hubei	1116.91	7339	15.22
Hunan	1313.12	7743	16.96
Guangdong	599.58	6299	9.52
Guangxi	642.48	4788	13.42
Sichuan	1168.97	12091	9.67
Guizhou	523.97	3185	16.45
Yunnan	437.39	4150	10.54
Shaanxi	932.97	4801	19.43
Gansu	538.39	3519	15.30
Qinghai	71.85	515	13.95
Ningxia	112.24	855	13.13
Xinjiang	136.76	2941	4.65

Source: SSB, ZNTN, 1985-1993.

Chapter 7

Changes in Total Factor Productivity and Sources of Yield Growth

7.1 Introduction

The preceding chapter estimated respectively the production functions of wheat, rice and corn. In this chapter, the estimated output elasticities with respect to individual inputs are used as weights to compute the total factor productivity index (hereafter TFPI). Two major issues will be examined.

The first concerns growth patterns of total factor productivity. As shown in Chapter 4 and Chapter 5, between 1978 and 1990, both output and yields of grain increased dramatically but unevenly. The major increases occurred in the early 1980s, while between 1985 and 1990, output and yields increased slowly for the country as a whole and for many individual provinces. This chapter examines the growth patterns of total factor productivity and investigates their relationship to the changes in output. It also analyses the impact of government policies in grain marketing and in agricultural investment on the growth patterns of total factor productivity. Based on this examination, some implications for changes in farmers' production behaviour and their effects on total factor productivity will be considered and issues that need further study in the succeeding chapter will be highlighted.

The second issue to be tackled in this chapter is the sources of yield growth. Instead of looking at the sources of total output, the approach focuses on investigating the contributions of inputs and total factor productivity to the changes in grain yields. During the period studied, decreases in grain sown areas represented the general trend at the national level and in most individual provinces. This trend, however, is partly associated with China's lack of arable land. As stressed in Chapter 5, the spectacular increase in grain output during the period studied can mainly be attributed to the great enhancement of yields. Looking at the sources of yield growth is, therefore, of practical importance for understanding the path of development of Chinese grain production.

This chapter is organised as follows: Section 2 computes the TFPI for wheat, rice and corn at the national level, as well as for individual provinces. Section 3 analyses the growth patterns of total factor productivity, their relationship to the changes in grain output and the effect of government policies on the performance of grain production. Section 4 investigates the sources of yield growth between 1981 and 1990, and during the two sub-periods, 1981-1984 and 1985-1990.[1] This is followed by a brief conclusion in Section 5.

7.2. TFPI and Patterns of Growth

7.2.1 Computing TFPI

As reviewed in Chapter 2, there are two most commonly used methods to measure TFPI. This study follows the Solow's geometric index. Based on the Cobb-Douglas production function and considering the effect of weather

[1] The sources before 1981 cannot be analysed because of the absence of data.

fluctuations, the formula for computing TFPI can be derived from the following formulas:

$$Ln(Y_{it}) = Ln\,(A_{it}) + \sum a_j\,Ln(X_{ijt}) + \varepsilon Ln(D_{it}) \qquad (7.1)$$

$$Ln(TFP) = Ln(A_{it}) = Ln(Y_{it}) - \Sigma a_j\,Ln(X_{ijt}) - \varepsilon Ln(D_{it}) \qquad (7.2)$$

where A_{it} is the total factor productivity of the i^{th} province at time t. Y_{it} is the output of the i^{th} province at time t. a_j is the output elasticity with respect to the j^{th} input. X_{ijt} stands for the j^{th} input in the i^{th} province at time t. D_{it} is the percentage of the areas affected by natural conditions in the i^{th} province at time t. ε is the parameter of weather conditions

Taking a specific year as the base to compute the TFPI during a certain period in comparison with the base year, form (7.2) then becomes:

$$TFPI = A_{it} / A_{i0} = \frac{Y_{it} / \exp\{\sum a_j Ln(X_{ijt}) + \varepsilon Ln(D_{it})\}}{Y_{i0} / \exp\{\sum a_j Ln(X_{ijo}) + \varepsilon Ln(D_{i0})\}} \qquad (7.3)$$

Subscript t and 0 stand for year t and the base year, respectively. The TFPI of wheat, rice and corn is to be computed separately using form (7.3). In the following computation of the TFPI, the year 1985 is taken as the base year. This is because one of the concerns of this study is to investigate the differences between the period prior to 1985 and the period after 1985 in terms of changes in total factor productivity. By taking 1985 as the base year, the changes during these two sub-periods can be observed more clearly.

7.2.2 Growth Patterns and the Spatial Distribution of Total Factor Productivity

1) Wheat

Table 7.1 shows that between 1981 and 1990, the TFPI of wheat increased significantly, both nationally and in many provinces. This indicates that the reforms have had positive effects on the improvement of total factor productivity. This point has been recognised and widely accepted by scholars both within China and abroad.

It is also noticed that the increase in total factor productivity mainly occurred between 1981 and 1984. In the second half of the 1980s, total factor productivity did not increase significantly at the national level. In individual provinces, it either increased modestly, or stagnated, or even decreased. From this point of view, the effects of the reforms were dramatic only during the early period. In the later years, the effects were much less impressive. This pattern of the changes in total factor productivity is similar to the changes in wheat output and yields during the same period, which are shown in Table 4.2 and Table 5.1, respectively. The similar patterns indicate that during the period studied, changes in total factor productivity were largely responsible for the growth patterns of output and yield.

Looking at the spatial distribution of changes in total factor productivity, it can be seen that over the entire period studied, the growth was more significant in the north and northwest provinces. In the southeast and central provinces, the increase was relatively minor. However, a closer look finds that this spatial pattern only became prominent after 1985. Although there were some variations in terms of changes in total factor

Table 7.1 Total Factor Productivity Index of Wheat, 1981-1990*

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Changes 1981-90	1981-84	1985-90
National**	83	93	97	103	100	101	96	93	100	102	19	20	2
Beijing	100	86	106	104	100	107	112	113	136	129	29	5	29
Tianjin	72	78	96	93	100	90	86	91	117	109	37	21	9
Hebei	83	80	101	100	100	107	103	105	116	114	31	18	14
Shanxi	75	86	99	106	100	106	93	83	102	106	31	31	6
Neimenggu	86	102	107	90	100	93	95	92	108	106	20	4	6
Heilongjiang	90	86	118	103	100	102	94	100	108	120	30	13	20
Shanghai	80	101	82	107	100	108	86	100	89	92	12	27	-8
Jiangsu	86	101	93	100	100	112	103	105	95	99	13	14	-1
Anhui	90	96	106	110	100	102	105	91	89	95	5	20	-5
Shandong	84	77	99	100	100	105	98	90	96	93	9	16	-7
Henan	86	85	97	112	100	110	114	106	108	99	13	25	-1
Hubei	90	114	99	105	100	115	109	100	96	91	1	15	-9
Sichuan	70	95	103	101	100	97	99	88	88	98	28	31	-2
Guizhou	90	86	101	105	100	108	98	103	98	108	18	14	8
Yunnan	82	81	101	102	100	90	106	107	87	101	20	21	1
Shaanxi	84	100	105	98	100	103	105	93	102	95	11	14	-5
Gansu	79	95	97	102	100	101	95	83	104	118	39	23	18
Qinghai	73	90	90	100	100	95	98	94	98	103	31	27	3
Ningxia	87	99	106	105	100	110	87	84	109	109	22	18	9
Xinjiang	82	79	98	103	100	118	107	98	98	103	21	21	3

* Weights used in computing the aggregate input are from Table 6.4.

** The changes in total factor productivity at the national level are computed on the basis of national average figures in the SPB household survey used in this study. This is also applied in computing the national TFPI of rice and corn in Table 7.2 and Table 7.3.

productivity between 1981 and 1984, no apparent patterns in spatial distribution can be identified. During the second sub-period, despite the overall modest changes, the spatial patterns were rather distinct. The provinces in the southeast and central regions, such as Jiangsu, Anhui, Shandong, Henan, Hubei and Sichuan experienced a general decrease. In accordance with this decrease, wheat yields increased much more slowly (or even decreased in some of these provinces), compared with the previous period and with many other provinces during the second sub-period (see Table 5.6).

The situation in most provinces in the north and northwest areas was somewhat different from the southeast and central provinces during the second sub-period. In Beijing, Tianjin, Hebei, Shanxi, Neimenggu, Heilongjiang, Guizhou, Gansu and Ningxia, total factor productivity experienced an increase, though the increase was modest compared with the previous period. It is also noted that, except for Hebei and Heilongjiang, the role of these provinces in national wheat production is less important due to their small shares of wheat sown areas in the national total.

It is noteworthy that the southeast and central areas have relatively good conditions for the production of many different kinds of crops, including wheat, rice and cash crops, such as cotton and oil-bearing seeds. This means that there are less natural constraints on farmers' production choices. Meanwhile, the southeast and the central areas are also the areas where the rural enterprises developed rapidly during the reform period. This provided more opportunities outside of agricultural production. In contrast, agricultural production in the provinces in the north and northwest is often restricted by natural environments, and fewer choices of crops are available in these provinces. Compared with the southeast and central areas, during the reform period, the development of rural enterprises in some of the north and northwest provinces was relatively slow. Bearing this in mind, one would expect that these spatial patterns of total factor productivity changes have some relationship to the level of rural economic development and the choices among different crops.

2) Rice

Table 7.2 shows that the national level of total factor productivity of rice increased between 1981 and 1990. However, this increase only occurred between 1981 and 1984. Between 1985 and 1990, total factor productivity did not increase, but decreased slightly. This result suggests that during the second sub-period, rice production performed relatively poorly. The decrease in total factor productivity at the national level was certainly one of the reasons for the slower increase in rice output and yields during this period.

In individual provinces, the situation is similar to that exhibited at the national level. During the whole period between 1981 and 1990, there was a general improvement in total factor productivity in all the producing provinces. Again, this mainly occurred before 1985. After then, all provinces had either a little increase or a decrease.

It is noted that during the second sub-period, in many northern rice (Japonica rice) producing provinces, including Beijing, Tianjin, Liaoning, Jilin, Heilongjiang and Ningxia, total factor productivity decreased or remained stable. This is distinct from the relatively large increase in the yield of rice in these provinces as shown in Table 5.6. The decrease or the stagnation of total factor productivity in northern rice producing provinces indicates that the

Table 7.2 Total Factor Productivity Index of Rice, 1981-1990*

											Changes		
Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1981-90	1981-84	1985-90
National	85	93	96	101	100	101	96	90	93	97	12	16	-3
Beijing	83	96	110	86	100	112	101	98	92	90	7	3	-10
Tianjin	68	95	82	79	100	105	91	98	89	83	15	11	-17
Liaoning	84	86	108	116	100	107	107	107	106	101	17	32	1
Jilin	86	89	106	107	100	107	112	106	101	102	16	21	2
Heilongjiang	73	61	93	94	100	99	89	99	102	100	27	21	0
Shanghai	73	82	116	122	100	117	103	107	104	105	31	49	5
Jiangsu	89	88	102	103	100	114	107	106	106	103	13	14	3
Zhejiang	89	92	89	109	100	109	104	106	101	109	20	20	9
Anhui	88	109	107	120	100	111	98	102	102	107	19	31	7
Fujian	84	94	100	98	100	93	96	87	90	93	9	14	-7
Jiangxi	82	96	102	101	100	104	100	91	92	95	13	19	-5
Henan	97	83	114	96	100	105	97	97	99	107	10	-1	7
Hubei	80	78	84	89	100	99	84	87	89	97	17	9	-3
Hunan	72	82	99	100	100	107	102	101	110	105	33	28	5
Guangdong	81	89	93	102	100	100	100	95	96	103	22	22	3
Guangxi	83	89	92	97	100	88	99	86	107	101	18	14	1
Sichuan	75	87	94	102	100	104	98	98	100	107	32	27	7
Guizhou	75	74	103	105	100	91	96	98	102	106	31	30	6
Yunnan	97	96	106	116	100	101	107	107	100	108	11	19	8
Ningxia	78	89	68	99	100	103	100	100	103	100	22	21	0

*Weights used in calculatiing the aggregate input are from Table 6.4.

increased output of northern rice can mainly be attributed to the increase in inputs.

It is also noted that during the second sub-period, the total factor productivity of rice in many of the southeast and central provinces even increased slightly, though there were variations. This is different from the situation of wheat production in these provinces. This may imply that farmers make different efforts in producing different grain crops when choices are available. It seems that in the southeast and central provinces, where both wheat and rice are important, wheat production is experiencing a decrease and rice production is, to some extent, being strengthened.

3) Corn

Between 1981 and 1990, the national level of total factor productivity of corn increased significantly. Although this increase mainly occurred in the early years of the reforms, some progress was also recorded in the second sub-period, implying a relatively better performance of corn production. In addition, compared with wheat and rice, changes in total factor productivity of corn were relatively smooth both before and after 1985. This feature is in contrast to the large fluctuations in the corn yield during the period studied.

Looking at the changes in individual provinces, it can be seen that although the first sub-period experienced a greater increase, the increase during the second sub-period in many large corn producing provinces, such as Shanxi, Liaoning, Jilin, Heilongjiang and Henan, was also significant.[2] The significant increase in total factor productivity, no doubt, contributed to the

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[2] These five provinces accounted for 47.5 percent of the total corn output in 1990 (SSB, 1991, p.350).

Table 7.3 Total Factor Productivity Index of Corn, 1981-1990*

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Changes 1981/90	1981/84	1985/90
National	84	86	94	100	100	100	102	97	101	103	19	16	3
Beijing	77	85	83	78	100	106	94	87	92	96	19	1	-4
Tianjin	70	88	85	85	100	107	95	85	98	93	23	15	-7
Hebei	72	76	89	94	100	114	102	105	112	111	38	21	11
Shanxi	83	85	114	101	100	104	97	107	110	111	28	18	11
Neimenggu	77	73	101	84	100	110	104	103	115	107	30	6	7
Liaoning	82	79	104	93	100	114	112	99	103	108	26	11	8
Jilin	61	72	97	108	100	119	109	116	102	113	52	47	13
Heilongjiang	95	87	112	106	100	127	97	128	130	139	44	12	39
Jiangsu	86	75	89	95	100	103	94	105	101	92	6	9	-8
Anhui	68	82	80	94	100	93	89	83	105	94	26	26	-6
Shandong	71	83	93	98	100	95	104	101	97	103	33	27	3
Henan	74	67	114	111	100	104	116	111	125	111	37	37	11
Hubei	91	78	88	101	100	100	105	82	89	92	1	9	-8
Sichuan	77	97	94	103	100	91	85	88	90	94	17	26	-6
Guizhou	96	86	95	103	100	112	99	93	102	104	8	6	4
Yunnan	97	92	91	106	100	97	92	98	104	102	5	9	2
Shaanxi	61	84	99	111	100	89	98	96	97	98	37	50	-2
Gansu	64	72	86	100	100	104	102	104	103	108	44	37	8
Xinjiang	90	90	96	92	100	112	92	107	110	125	35	2	25

*Weights used in calculating the aggregate input are from Table 6.4.

relatively large growth in corn output. In many other provinces, however, the decrease in total factor productivity was the general trend during the second sub-period. The spatial pattern of total factor productivity changes suggests that corn production tended to become more efficient in large producing provinces, whereas in many minor producing provinces, production performed rather poorly.

7.3 Analysis of The Growth Patterns of the TFPI for Wheat, Rice and Corn

As shown above, total factor productivity increased nationwide during the period studied, though the pace was uneven. Generally speaking, for all the three grain crops, the dramatic increase in total factor productivity occurred in the first sub-period of the reforms. After 1985, total factor productivity did not record significant changes. This pattern is basically consistent with the growth pattern of grain output.

As mentioned in Chapter 5, it has been well documented and widely accepted that the growth patterns of total factor productivity during the period studied were closely related to the process of the institutional reforms, i.e., the implementation of the HRS. The rapid growth of total factor productivity was stimulated by the HRS through the shift of production towards its frontier. By 1984, the implementation of the HRS was completed and, accordingly, the one-off gains from this decollectivisation were depleted. This was one of the important reasons for the slow down in growth after 1985. Since much previous work has dealt with this issue, this study will not discuss it further. Rather, it concentrates on analysing the effect of market reforms after 1985 and changes in state agricultural investment during the reform period on total factor productivity.

One noticeable feature can be observed in Table 7.1, Table 7.2 and Table 7.3. In the first two years of the second sub-period, 1985 and 1986, total factor productivity was basically unchanged for all the three grain crops compared with the level of 1984. This is somewhat different from the situation exhibited in grain output during the same period. As shown in Table 4.2, in 1985 and 1986, there was a large drop in grain output at the national level compared to the level of 1984 (except for wheat in 1986). However, the decrease in total factor productivity did not occur until 1987. In considering all the three grain crops, total factor productivity dropped to the lowest level in 1988 during the second sub-period. The inconsistent patterns in total factor productivity and output changes after 1985 reflect partly the inconsistency of the marketing polices during this period.

After the record harvest in 1984, the government introduced the grain contract system to replace the compulsory quota purchase system. At the same time, the government relaxed marketing and pricing controls over most non-grain products. The new polices were unfavourable to grain production as they lowered the relative price of grain. It is widely considered that the implementation of new policies was partly responsible for the stagnation of grain output after 1985 (Colin Carter and Zhong Funing, 1988; Zheng Zhong, 1988; Yang Hong, 1991; Zhou Zhangyue, 1992). However, the effect of these new policies on total factor productivity was more complicated.

Under the contract purchase system, farmers were supposed to have more freedom to manage their own production. Theoretically, farmers were free to sign or not to sign contracts with the state for grain delivery. Farmers were also free to determine whether to increase or decrease inputs and outputs. It is to be expected that when grain prices are unfavourable, farmers will reduce inputs and transfer the resources to other sectors which are more profitable. This situation happened in 1985 and 1986. The SPB survey data show that in 1985, all inputs in grain production decreased to some extent. This inevitably led to a decrease in grain output. However, this did not result in a simultaneous decrease in total factor productivity.

In practice, the new policies implemented in 1985 did not last for long. After only one year, the grain contract became compulsory in 1986. The contract was therefore not much different from the grain quota practiced before 1984. The retreat of the government from the contract delivery to compulsory sales was, however, understandable and perhaps inevitable. The government's aims in introducing contract purchase were twofold: firstly, to reduce grain subsidies caused by increasing grain purchase prices while retaining the lower grain retail price. Contract purchase abolished the premium price to the above-quota delivery which was available before 1984. This reduced the average price paid to farmers. Secondly, it aimed to reduce the amount of grain purchase in order to alleviate the problems of grain storage and to avoid the obligation to purchase grain when the grain supply was in surplus.[3] As a consequence of the two initiatives, it was hardly surprising that when grain supply was in shortage, the government would strengthen its administrative control over grain purchase. This was the situation after 1986 when grain output decreased sharply and it became difficult for the state grain bureaus to purchase grain. The government then announced that the grain contract was still an obligation for farmers and needed to be fulfilled. Farmers were persuaded and sometimes forced to increase output and to sell grain to the state. Low relative prices meant that

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[3] Although the government promised a minimum guaranteed price for purchasing the grain that farmers were willing to sell, this price was never implemented because in 1985, the drastic drop of grain output pushed the free market price up significantly and farmers were not willing to sell grain to the state.

farmers had no enthusiasm in producing grain, but administrative control limited their freedom in determining their production. Total factor productivity of grain production would thus be lowered by the lack of incentives and by the mandatory requirements. This argument is supported by Lin Yifu's study (1991), which emphasised the importance of free production decisions and choices for increasing the efficiency of agricultural production.

It has been shown that there were variations among the three grain crops in the growth patterns of total factor productivity. This is likely to be related to different levels of supervision of production for different types of grain. Comparing the three grain crops, during the second sub-period the lowest level for corn production, which occurred in 1988, was less than 3 percent below to the level of 1985. For wheat and rice, the ranges were relatively wide. The lowest level for wheat in 1988 was about 7 percent lower than the level of 1985, and for rice, it was 10 percent lower. This feature is different from the situation in the yield of these grain crops. As shown in Figure 5.1, the fluctuation in corn yield was larger than rice and wheat. The contrast between the yield and total factor productivity may imply that farmers had greater freedom to choose between producing and not producing corn than in producing wheat and rice. This freedom enabled farmers to respond to external factors, including government policies and the marketing situation, more rationally in terms of profit making.

Because of the lack of statistical data, it is difficult to prove the above point from official data. However, empirical evidence shows that the rationed grain supplied to urban residents is dominated by wheat in the north and by rice in the south. The proportion of corn in the rationed grain supply is small. According to an urban resident household survey, coarse grain consumption (including corn and other miscellaneous grain crops) accounts only for 7-9 percent of the total direct food grain consumption. The direct consumption of corn is smaller than this proportion (SSB, Survey Team of Urban Socio-economy, 1987, 1991).[4] Assuming that the state control over grain production is mainly aimed to ensure the rationed grain supply to the urban residents, it is reasonable to believe that the state grain purchase is dominated by wheat and rice and that the control over corn production is thus relatively relaxed compared to the control over wheat and rice. Bearing in mind that the output of corn is almost the same as wheat, the small state purchase of corn means a large amount of corn is handled by farmers themselves. It also means that corn production is more market orientated compared with the other two grain crops.[5] The output fluctuation of corn may therefore be largely due to constant changes in the market situation. This, however, does not necessarily lower the total factor productivity. The situation exhibited in corn production may suggest that a lower level of control over grain production may be conducive to the improvement of total factor productivity.

The more efficient performance of corn production may, however, also be partly attributable to its low initial level. In China, unlike the case for rice, corn yield was relatively low compared to the international standard in the early 1980s. This low starting level meant a high potential for improving yields through applying modern technology and improving technical efficiency.

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4 For rural residents, in 1990, the annual direct grain consumption was 262 kg/per capita. Of this, coarse grain consumption (including corn, millet, sorghum and beans) only accounted for less than 18 percent (SSB, *ZTN*, 1991, p.303).

5 Although a large proportion of corn is used as feed grain, it will not affect the above assumption as most meat is produced by farmers in rural areas. Central control over meat production and marketing is relatively weak.

Table 7.4 State Budgetary Expenditures on Agriculture, 1978-1989*

(100 million yuan, current price)

Period	Total agricultural investment	As % of total state budgetary	Investment in agricultural capital construction	As % of total investment in capital construction
4th FYP** (1971-1975)	80.24	10.18	34.95	11.09
5th FYP (1976-1980)	138.71	13.24	47.61	11.91
1981	110.21	9.90	24.15	7.31
1982	120.48	10.40	28.81	9.32
1983	132.83	10.30	34.25	8.95
1984	141.30	9.10	33.63	6.88
1985	153.62	8.30	37.73	6.46
1986	184.20	7.90	43.87	6.53
1987	195.46	6.50	46.81	7.45
1988			39.64	6.26
1989			43.39	7.10

* This table uses the broad concept of agriculture.
** FYP means "Five-Year Plan".

Source: SSB, 1990, p.239, 1991, p.218.

The reduction in state agricultural investment during the reform period was also responsible for the uneven growth patterns of total factor productivity. As shown in Table 7.4, the share of agricultural investment in total state budgetary expenditure declined during the reform period compared with the preceding period. The share of investment in agricultural capital construction as a proportion of state total investment in capital construction also decreased. Since the reform, the state has tended to retreat from the role of the key investor in agriculture. This, to some extent, would have been an inevitable result of the increase in grain prices and the relaxation of central control over grain production, two key measures of the reform polices (Watson, 1989; Yang Hong, 1991; Tsang Shu-ki and Cheng Yuk-shing, 1994). The implementation of these two policies meant that the state was no longer able to extract as much funds from the agricultural sector as before the reforms. As a response, the state reduced its investment in this sector.

The reduction in state investment in agriculture will not necessarily lead to a "crisis of accumulation", if other sources of investment take up the role of the state. However, much empirical evidence shows that the investment of both local governments and farmers has tended to flow out of agricultural production, due to the high opportunity costs of capital (details of farmers' grain production behaviour will be analysed in Chapter 8). For individual households, much investment in fixed assets has been in residential housing (Yang Hong, 1991; Tsang Shu-ki and Cheng Yuk-shing, 1994).

The lack of investment has constrained agricultural research, the development of new technology and the construction of agricultural infrastructure. This has no doubt contributed to the stagnation of grain output in the late 1980s. With production moving close to its technical potential, further increases in total factor productivity need to rely on the improvement of technology. The reduction in agricultural investment has constrained this improvement.

It is worth pointing out that after the drastic decline in grain output in 1985 and 1986, the government re-emphasised the importance of improving technology. In the late 1980s, "relying on technology to re-boost agricultural production (*keji xingnong*)" was encouraged. From 1987, the Ministry of Agriculture and the Ministry of Finance launched a "bumper harvest project (*fengshou jihua*)". The purpose of this project is to promote the development and adoption of new technologies to increase output and production efficiency (Ministry of Agriculture, 1990, p.331). This effort has been conducive to the recovery in grain output and total factor productivity after 1989. It is reported that this project has been particularly successful in the Huang-Huai-Hai Plain where the corn production is concentrated (ECCAY, *ZNN*, 1990 and 1991).

7.4 Accounting for Sources of Yield Growth

As discussed in Chapter 5, one of the remarkable features in the development of grain production during the reform period has been the great enhancement in grain yields. It is of significance to investigate the sources of yield growth and to see how the growth patterns were related to the changes in total factor productivity and inputs.

7.4.1 The Method of Accounting for Yield Growth

The formula for accounting for yield growth can be derived from the Cobb-Douglas production function. It is specified as the following form in the context of this study:

$$Ln(Y_{it}) = Ln(A_{it}) + aLn(S_{it}) + bLn(L_{it}) + cLn(F_{it}) + dLn(K_{it}) + E_{it} \qquad (7.4)$$

where Y is output, S, L, F and K stand for inputs of land, labour, chemical fertiliser and other capital inputs, respectively. E is the residual, indicating the effect of weather conditions, estimation and data recording errors, and other random factors.[6] A is the total factor productivity, and a, b, c and d, are the

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[6] For the sake of simplicity, and considering the random nature of weather conditions, the variable for weather conditions was aggregated into the category of random effects. This aggregation does not affect the observation of the contribution of inputs and total factor productivity.

output elasticity of the respective inputs. Subscripts i and t stand for the i^{th} province at time t.

In Chapter 6, the elasticity of labour input is statistically insignificant. It is therefore excluded in the following analysis. Again, any effect of labour input on yield changes may be reflected by the factors considered in the following analysis. As the statistical tests support constant returns to scale for wheat, rice and corn, form (7.4) then can be converted to:

$$Ln(y_{it}) = Ln(A_{it}) + cLn(f_{it}) + dLn(k_{it}) + E_{it} \qquad (7.5)^7$$

where y, f, k and E denote, respectively, yield, per unit input of chemical fertiliser, other capital and the effects of random factors. Taking the first derivative of the form (7.5) with time t, it becomes:

$$\frac{\partial Ln(y_{it})}{\partial t} = \underset{(1)}{\frac{\partial Ln(A_{it})}{\partial t}} + c\underset{(2)}{\frac{\partial Ln(f_{it})}{\partial t}} + d\underset{(3)}{\frac{\partial Ln(k_{it})}{\partial t}} + \underset{(4)}{\frac{\partial E_{it}}{\partial t}} \qquad (7.6)$$

The theoretical concept of the form (7.6) is that changes in yields can occur as a result of changes in total factor productivity and changes in inputs. The left-hand side represents the growth rate of grain yields. The first term on the right-hand side indicates the contribution of total factor productivity to the yield growth. The second and the third terms are the contributions of chemical fertiliser and other capital inputs, respectively. The fourth term captures all the random effects on the changes in grain yields.

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[7] The procedure for this conversion has been illustrated in Chapter 6.

7.4.2 Accounting for the Yield Growth of Wheat, Rice and Corn

In accounting for yield growth, the period from 1981 to 1990 and the two sub-periods: 1981-84 and 1985-90, are considered. The details of the accounting for wheat, rice and corn are shown in Table 7.5, Table 7.6 and Table 7.7, respectively.

The tables show that during the entire period studied, grain yields increased in all provinces, though the extent of the increases varied. The contribution of total factor productivity was an important source of the yield growth. With respect to the overall national production, its contribution was almost equal to the combined contribution of chemical fertiliser and other capital inputs. This feature can be seen in many provinces.

As total factor productivity increased rapidly in the early 1980s and slowed down in the second half of the decade, it is not surprising that the contribution of total factor productivity to yield growth also changed in this fashion. Table 7.5 shows that between 1981 and 1984, the contribution of total factor productivity was 16 percent out of the total 22.3 percent of the wheat yield growth. However, between 1985 and 1990, it only accounted for 1.5 percent out of the total 13.8 percent of the yield growth. A similar situation existed in rice and corn production.

The contribution of material inputs: chemical fertiliser and other capital inputs, changed in different fashions from total factor productivity. Comparison between the two sub-periods shows that during the early sub-period, the contributions of chemical fertiliser and other capital inputs were small and they became large in the second sub-period. The survey shows that of the other capital inputs, the purchased agricultural producer goods

Table 7.5 Sources of Growth of Wheat Yields, 1981-1990

	Changes % 1981-1990					Changes % 1981-1984					Changes % 1985-1990				
	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R
National	31.6	7.6	7.4	14.5	2.1	22.3	1.2	1.4	16.0	3.8	13.8	5.9	6.2	1.5	0.3
Beijing	32.8	5.5	9.2	17.7	0.3	6.4	3.5	3.5	-1.6	1.0	34.2	8.6	7.9	22.3	-4.7
Tianjin	59.4	12.1	9.6	36.4	1.4	32.9	6.3	-1.7	16.1	12.2	32.9	8.9	10.3	8.1	5.6
Hebei	38.9	11.1	9.9	21.2	-3.3	28.3	8.8	8.5	10.6	0.3	20.0	5.3	3.3	11.9	-0.5
Shanxi	47.6	9.7	11.2	29.0	-2.4	42.5	7.8	7.8	29.2	-2.4	17.5	4.4	5.3	5.4	2.4
Neimenggu	31.2	10.5	8.5	12.8	-0.6	7.7	7.5	6.0	-2.2	-3.7	25.3	9.3	6.7	5.4	3.9
Heilongjiang	33.7	11.0	11.1	9.0	2.6	9.8	5.6	6.1	-6.8	4.9	37.6	5.4	5.6	17.0	9.7
Shanghai	11.8	2.9	-3.2	8.6	-0.7	17.9	-2.4	-6.9	21.3	6.0	-7.0	0.5	5.3	-10.5	-2.3
Jiangsu	17.0	6.5	4.5	7.8	-1.8	16.9	1.9	3.4	8.5	3.1	0.2	4.4	1.6	-0.9	-4.9
Anhui	25.0	8.8	6.6	5.3	4.3	21.3	4.8	4.3	13.4	-1.2	5.5	2.5	-1.2	-5.0	9.2
Shandong	20.0	8.9	7.9	8.7	-4.6	14.3	2.9	0.9	11.4	-0.8	2.6	6.0	9.5	-9.0	-3.8
Henan	22.0	8.8	7.0	6.8	-0.6	22.4	3.7	1.0	17.3	0.5	12.5	6.5	6.0	-1.1	1.2
Hubei	10.9	9.8	10.9	-8.0	-1.8	16.8	6.1	6.9	-1.1	4.9	-5.2	5.0	2.7	-1.8	-11.2
Sichuan	29.9	6.8	2.5	23.5	-2.9	29.8	3.7	0.3	26.1	-0.2	3.2	3.6	3.0	-2.6	-0.7
Guizhou	15.3	6.1	7.2	8.8	-6.7	9.0	0.7	6.3	5.6	-3.7	13.4	2.2	2.1	7.7	1.4
Yunnan	25.2	5.8	4.7	10.4	4.3	16.5	0.0	-1.2	11.2	6.5	18.1	5.3	4.9	1.5	6.3
Shaanxi	25.3	11.7	8.1	5.3	0.2	28.5	10.4	8.9	8.3	0.9	7.1	0.9	6.2	-5.5	5.4
Gansu	39.8	7.6	7.0	26.8	-1.7	23.9	1.4	3.2	15.5	3.8	24.5	5.6	2.8	15.1	1.0
Qinghai	30.6	2.0	2.5	24.7	1.4	22.0	-4.0	-0.8	21.9	4.8	10.9	4.4	2.6	3.2	0.7
Ningxia	28.7	3.7	4.8	17.1	3.1	2.0	-6.0	-4.0	0.9	7.0	22.2	2.2	10.4	8.0	1.6
Xinjiang	51.2	15.3	17.3	16.3	2.3	35.1	10.2	8.6	16.4	-0.1	24.7	6.5	10.5	2.5	5.2

CF: chemical fertiliser; K: other capital inputs; R: residual.

Source: Data for yield and inputs are from the SSB household survey.

Table 7.6 Sources of Yield Growth of Rice, 1981-1990

	Changes % 1981-1990					Changes % 1981-1984					Changes % 1985-1990				
	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R
National	25.1	4.8	8.0	12.8	-0.6	20.2	1.9	2.7	15.9	-0.4	7.9	3.1	6.1	-3.7	2.3
Beiing	17.6	2.9	9.5	3.5	1.7	1.0	-0.1	3.4	-1.2	-1.2	4.1	4.2	7.2	-10.6	3.3
Tianjin	35.7	5.4	8.4	25.1	-3.3	29.8	3.5	7.6	21.5	-2.8	2.1	4.8	10.9	-10.6	-3.0
Liaoning	19.8	1.0	6.2	13.7	-1.1	27.8	2.0	3.8	25.3	-3.3	12.1	1.5	6.1	0.6	4.0
Jilin	26.0	3.5	9.7	12.3	0.4	24.0	2.2	6.3	17.1	-1.7	17.4	1.2	6.9	1.6	7.8
Helongjiang	42.3	5.7	11.1	22.4	3.1	35.2	6.6	9.9	17.7	1.0	5.4	-1.0	1.2	-0.4	5.6
Shanghai	40.2	2.4	6.0	37.4	-5.6	44.5	-6.8	0.2	46.4	4.7	18.9	4.8	7.3	4.5	2.3
Jiangsu	31.0	4.2	6.4	23.4	-3.0	25.7	0.6	0.8	23.6	0.7	27.9	4.0	5.2	9.5	9.3
Zhejiang	20.1	5.4	5.9	15.2	-6.3	21.0	4.5	3.3	15.4	-2.2	7.8	1.2	2.0	8.2	-3.6
Anhui	20.2	1.6	1.9	14.6	2.1	24.9	-2.0	-1.8	23.4	5.2	13.3	4.5	5.0	6.8	-3.0
Fujian	20.2	3.9	7.5	6.9	1.9	19.0	1.2	0.3	11.9	5.5	3.1	2.4	7.1	-7.7	1.2
Jiangxi	27.5	5.5	10.0	14.8	-2.8	25.9	1.9	4.2	20.3	-0.6	5.2	4.5	6.7	-5.6	-0.4
Henan	12.0	6.8	5.8	6.6	-7.3	-8.9	1.5	5.1	-14.0	-1.4	12.5	7.0	3.8	6.5	-4.8
Hubei	31.3	6.8	9.3	21.1	-5.8	24.7	5.6	6.7	14.2	-1.8	-0.3	1.6	3.8	-3.0	-2.8
Hunan	27.5	1.3	1.8	28.5	-4.0	22.9	-2.2	-0.1	24.9	0.3	2.5	0.3	-0.9	5.1	-1.9
Guangdong	24.2	2.6	5.1	18.3	-1.8	21.1	-0.3	2.8	17.7	0.9	11.0	0.7	3.8	3.1	3.4
Guangxi	28.9	5.8	11.6	14.2	-2.6	16.0	1.5	4.4	11.1	-1.1	10.7	3.9	6.9	0.9	-1.0
Sichuan	32.7	3.3	3.6	31.7	-5.9	27.2	-0.2	0.2	28.6	-1.4	12.1	3.4	4.3	6.3	-2.0
Guizhou	35.6	3.8	5.7	33.1	-7.0	27.6	-8.0	-1.3	32.3	4.5	15.1	5.2	5.4	6.1	-1.6
Yunnan	21.5	5.7	9.8	7.2	-1.2	11.5	1.1	-0.1	13.4	-2.9	17.4	3.1	5.9	7.6	0.9
Ningxia	52.8	6.3	14.0	37.5	-5.0	46.7	5.1	10.6	36.8	-5.7	11.2	0.9	5.9	0.4	4.0

Source: same as in Table 7.5.

Table 7.7 Sources of Yield Growth of Corn, 1981-1990

	Changes % 1981-1990					Changes % 1981-1984					Changes % 1985-1990				
	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R	Yield	CF	K	TFP	R
National	33.3	9.5	6.4	17.8	-0.3	19.5	1.2	2.2	16.1	0.1	16.9	7.6	5.3	2.2	1.7
Beijing	20.2	3.5	3.5	16.3	-3.1	-2.7	2.5	1.8	-3.3	-3.6	17.0	13.0	6.6	-4.4	1.7
Tianjin	30.3	8.5	5.2	21.3	-4.7	4.0	-4.3	-3.5	14.0	-2.3	9.3	11.7	9.3	-8.0	-3.7
Hebei	32.9	5.9	1.1	31.8	-5.8	20.0	2.8	1.9	19.4	-4.1	14.3	6.8	1.3	9.6	-3.4
Shanxi	30.5	9.8	5.0	21.8	-6.2	13.6	7.6	1.0	14.1	-9.0	26.4	10.8	6.6	9.7	-0.7
Neimenggu	45.0	13.5	10.8	24.8	-4.2	20.5	11.7	7.7	3.3	-2.1	23.9	8.1	6.6	6.9	2.3
Liaoning	21.6	3.0	0.4	22.9	-4.8	6.4	3.8	0.1	10.5	-8.0	16.5	3.7	2.4	7.8	2.6
Jilin	58.7	13.3	11.1	32.0	2.2	52.6	9.2	9.0	29.3	5.2	23.7	6.2	4.1	11.4	2.0
Heilongjiang	48.9	14.8	10.6	22.9	0.6	28.6	11.4	9.7	7.4	0.1	35.0	7.1	1.8	21.6	4.4
Jiangsu	24.2	6.7	4.4	6.1	6.9	19.4	3.6	-0.6	9.0	7.4	2.5	7.2	5.5	-9.1	-1.1
Anhui	33.3	9.4	6.4	24.8	-7.2	12.5	-9.7	-6.3	24.5	4.0	9.4	9.5	6.4	-6.5	-0.1
Shandong	26.6	4.3	4.3	25.8	-7.8	16.2	-0.4	0.8	21.7	-5.9	12.4	5.5	4.2	3.3	-0.6
Henan	29.6	2.2	8.4	25.4	-6.4	12.9	-3.2	1.7	18.3	-3.9	22.3	8.6	5.7	9.6	-1.6
Hubei	30.7	12.9	13.0	12.2	-7.4	21.7	5.4	5.8	19.8	-9.4	-1.0	5.2	7.8	-8.4	-5.5
Sichuan	22.7	10.3	5.2	14.5	-7.3	24.5	2.8	1.7	22.1	-2.0	5.1	7.1	4.7	-6.3	-0.5
Guizhou	9.2	4.2	4.0	3.2	-2.3	4.4	0.1	1.5	1.6	1.2	7.7	-0.9	1.8	4.1	2.7
Yunnan	19.7	12.2	7.9	1.0	-1.4	6.6	5.1	1.2	4.9	-4.6	10.4	9.0	6.7	2.1	-7.4
Shaanxi	40.0	10.6	2.2	20.3	6.9	40.8	6.1	-3.3	29.5	8.5	8.6	5.4	4.3	-2.4	1.3
Gansu	49.1	10.2	8.1	32.4	-1.6	33.7	0.1	1.4	27.3	4.8	13.8	6.2	3.3	7.4	-3.1
Xinjiang	55.2	17.6	14.4	24.5	-1.3	15.7	7.9	8.6	6.0	-6.8	47.0	12.8	10.4	19.7	4.1

Source: same as in Table 7.5.

accounted for more than 90 percent.[8] This feature indicates that during the period 1981-1990, farmers' grain production tended to become more reliant on purchased producer goods (see Appendix 6.A for the items included in capital inputs). This meant that their grain production became more commercialised and as a result, the effect of the marketing and pricing situation became increasingly important for grain production.

The above features are also found in many individual provinces. Between 1981 and 1984, in most of the provinces, the contribution of material inputs was generally smaller than the contribution of total factor productivity, indicating the important role of total factor productivity in yield growth. However, between 1985 and 1990, the contribution of total factor productivity decreased, whereas both chemical fertiliser and other capital inputs contributed significantly to the yield growth. In most provinces, the sum of these two contributions was much larger than the contribution of total factor productivity. For all the three grain crops, during the second sub-period, the increases in material inputs were the main sources of yield growth. In some southeast and central provinces, such as Jiangsu, Anhui, Shandong, Henan, Hubei and Sichuan for wheat, Fujian, Jiangxi and Hubei for rice and, Jiangsu, Anhui, Hubei and Sichuan for corn, the contribution of material inputs was offset partly by the decrease in total factor productivity. As a result, the growth of yields was smaller than the combined contribution of chemical fertiliser and other capital inputs.

It is, however, noted that in most provinces, the differences between the two sub-periods in terms of the contribution of material inputs are not as large as the figures at the national level. Table 7.5 shows that for wheat

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[8] Here, it is assumed that only manure fertiliser can be produced by farm households themselves.

production at the national level, between 1981 and 1984 the contributions of chemical fertiliser and other capital inputs were only 1.2 percent and 1.4 percent, respectively, out of the total 22.3 percent of increase in the yield. However, in most provinces, the contributions of these two inputs were generally larger than the national figures. A similar situation can be seen in rice and corn production. This may imply that the national figures for changes in chemical fertiliser and other capital inputs were underestimated. This is plausible as the national figures provided in the SPB survey are the arithmetic average of the individual provinces, which may understate the contributions of these two inputs. Nevertheless, the provincial figures for changes in chemical fertiliser and other capital inputs clearly show the increased contributions to the yield growth in the second sub-period. The underestimated figures at the national level, therefore, do not affect the conclusion drawn from the analysis.

The values of the residual are relatively small at the national level as well as in most provinces, implying that the changes in fertiliser, other capital inputs and total factor productivity explained most of the changes in grain yields. It is, however, noted that the residuals at the national level were positive. This is due to the fact that weather conditions are the most influential element in determining the values of the residuals. The positive signs of the residuals reflect, to a certain extent, the favourable weather conditions in the end year of the period compared with the beginning year of the period under consideration. As shown in Figure 5.2, the areas affected by natural disasters at the national level were smaller in 1984 than in 1981. A similar situation can be seen in the comparison between 1990 and 1985. Therefore, when using 1981 and 1985 as base years in the accounting, the effects of weather conditions were expected to be positive. The values of residual, however, varied significantly among provinces. This is mainly because of large variations in the areas affected by natural disasters among different provinces in a given year.

7.4.3 The Comparison of the Sources of Yield Growth for Wheat, Rice and Corn

Comparisons among the three grain crops show some disparities in terms of the sources of yield growth. For the period as a whole, the contribution of total factor productivity was larger for corn and wheat yield growth and smaller for rice. In addition, although the increase in total factor productivity was the main contributor to rice yield growth between 1981 and 1990, this occurred primarily in the early years of the reforms. In the later years, the contribution became negative at the national level, as a result of the decrease in total factor productivity. This feature further supports the argument made earlier that rice production performed relatively poorly during the second sub-period. For corn production, the performance in the second sub-period was efficient as a relatively larger proportion of the yield growth was attributed to the improvement of total factor productivity.

The contribution of material inputs also differs among respective grain crops. In the case of rice production, the contribution of chemical fertiliser was generally smaller than that for wheat and corn production. This is associated with a relatively small marginal output of chemical fertiliser input in rice production (see Chapter 6). For corn production, the marginal output of chemical fertiliser is relatively high and this became one of the reasons for the relatively large contribution of chemical fertiliser input to the yield.

The contribution of other capital input was small for all the three grain crops during the first sub-period and increased significantly in the second sub-period. In this respect, there were no significant differences among different grain crops during the whole period studied as well as during the two sub-periods, though the figure for corn was slightly smaller than the other two. This feature may imply that farmers have been aware of the importance of other capital inputs rather than solely relying on chemical fertiliser. This is particularly so for rice production, plausibly due to the relatively large marginal output of other capital inputs (see Chapter 6).

7.5 Conclusion and Implications

The study shows that between 1981 and 1990, total factor productivity increased significantly and was an important source of yield growth. This result supports the opinion that the reforms have had positive effects on enhancing grain production efficiency. The comparison among the three grain crops, however, shows that the contribution of total factor productivity is larger for corn than for rice and wheat, suggesting a better performance for corn production during the period studied.

It is found that the changes in total factor productivity were uneven during the period studied. The major increase occurred in the early years of the reforms. In the later years, total factor productivity remained at the 1985 level, with fluctuations. For rice, there was a slight decrease. The trends of the changes in total factor productivity were generally consistent with the changes in grain output and yields during the same period, reflecting the important role of total factor productivity in grain production.

The effects of changes in market policies and the retreat of the central government from the role of the key investor were examined. It is argued that the changes in the level of the central control over grain marketing were partly responsible for the inconsistent changes of total factor productivity and grain output during the second sub-period. Moreover, the lack of agricultural investment constrained the development of technology and agricultural infrastructure, which was detrimental to the further improvement of total factor productivity.

It is also found that during the second sub-period, the provinces where grain production performed poorly were concentrated mainly in the southeast and central regions. In contrast, total factor productivity was relatively stable in some boarder provinces in the north and northwest regions, where the rural economy was relatively under-developed. This result implies that the level of rural economic development may have influenced the changes in total factor productivity.

The contributions of chemical fertiliser and other capital inputs to yield growth were significant for all the grain crops during the period studied. However, this was mainly the situation after 1985, indicating that farmers' grain production has become increasingly reliant on markets and therefore has became more commercialised.

Chapter 8

A Further Analysis of the Changes in Total Factor Productivity of Grain Production

8.1 Introduction

In the preceding chapter, the total factor productivity index for wheat, rice and corn was calculated. The result shows that during the period studied, total factor productivity increased significantly. There were, however, great variations across provinces and among different grain crops. This chapter focuses on examining the impact of rural reforms on total factor productivity growth from perspectives of rural economic development and changes in farmers' economic status. The aim is to explore in more detail the causes of the disparities in respective grain crops in relation to the spatial distributions and growth patterns of total factor productivity.

Since the late 1970s, the rural institutional and marketing reforms have brought about fundamental changes in the overall rural economy. The implementation of the HRS changed the methods of production management and income distribution. The marketing reforms meant that farmers became more aware of the opportunity costs of investment in different sectors of the rural economy. Against this general background, rural non-agricultural sectors, rural enterprises in particularly, experienced a dramatic growth. In 1990, the gross output value of rural enterprises was 15.42 times that of the 1978 figure. After 1987, the gross output value of rural enterprises exceeded the gross output value of agriculture (SSB, *ZTN*, 1991, p.378), indicating a fundamental change in the structure of the rural economy. Moreover, the decentralisation and marketisation in rural economic activities meant that the price mechanism became increasingly important in influencing farmers' production decisions. During the period studied, the increase in farmers' incomes was also remarkable. Between 1978 and 1990, farmers' average net income per capita increased from 133.57 yuan to 304.83 yuan at 1978 constant prices (SSB, *ZTN*, 1991, p.295).[1] This greatly strengthened farmers' resources and their investment capacity for capital-intensive production activities, such as rural industries. All these changes had an impact on farmers' production behaviour and, consequently, influenced the total factor productivity of grain production during the reform period.

In addition to the above changes, since the implementation of the HRS in the early 1980s, the farm size of individual households has also experienced some changes. For most farm households, the average grain sown area has tended to decline as a result of the increase in the number of households and the transfer of grain sown areas to non-grain crops and to non-agricultural activities (Huang Keyang, 1992; Tang Xiaoping and Sun Dongwang, 1992; and Chen Haiqing, 1992). Such trends are also expected to affect total factor productivity through the impact on economies of scale in household grain production.

This chapter uses a log-linear regression model to analyse the effects of various socio-economic factors on the growth patterns of total factor productivity between 1981 and 1990. Attention will be drawn to the responses of the respective grain crops to the different variables during the two sub-

[1] Net incomes refer to the incomes after deducting the costs for producer goods.

periods, and the mechanisms behind the disparities in provincial total factor productivity will be investigated.

The method used in this study to link total factor productivity and factors influencing total factor productivity is the so-called two-step procedure in the economics literature. The first step is to estimate total factor productivity, which, in this study, has been undertaken in Chapter 6 and Chapter 7. This chapter fulfils the second step, that is to regress the estimated total factor productivity on a set of variables that influence total factor productivity.[2]

An alternative to the two-step procedure is the one-step approach, which includes factors that are associated with total factor productivity in the estimation of production functions.[3] Compared with the one-step approach, the two-step procedure has a significant advantage: it can avoid multicollinearity problems in estimating production functions caused by including too many variables in the regression. In addition, this approach allows a more flexible choice of variables in the second step of the regression. However, the two-step procedure also has some shortcomings. As pointed out by Kumbhakar, et al (1991), the estimates of the parameters and error terms may be inconsistent due to the possible correlation between technical efficiency and the inputs.[4]

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[2] The two-step procedure has been used by Kalirajan (1989 and 1991) and Jefferson (1990).

[3] This approach has been used by Hayami and Ruttan (1985), Kumbhakar et al (1991) and Lin Yifu (1992).

[4] The choice of the two-step procedure is, however, also partly determined by the way the argument is structured in the preceding parts of the thesis. Furthermore, integrating these variables into the one-step procedure in the present study will cause a serious multicollinearity problem, which will make it impossible to carry out an economically significant analysis.

The chapter is organised as follows: Section 2 discusses the features of the above mentioned variables and specifies the data to be used in the regression model. Section 3 reports the estimated results from the model. Section 4 analyses the results and discusses their implications for the disparities among provinces and the respective grain crops in changes in total factor productivity during the two sub-periods. Section 5 summarises the main findings of the chapter.

8.2 The Attributes of Variables and Data Specifications

In theories of economic development, human capital is considered to be a key link in determining an individual firm's productive efficiency of inputs. Human capital itself is assumed to depend on factors which determine the individual's technical knowledge and the socio-economic environment in which the individual is working (Kalirajan, 1989). Accordingly, in analysing factors influencing the total factor productivity of agricultural production, variables relating to farmers' technical knowledge and to the socio-economic environment are selected. In empirical studies, however, the variables chosen are often determined by the questions the studies ask and the availability of data. For example, in a cross county study of agricultural production, Hayami and Rattan (1985) considered the effect of farmers' educational status on total factor productivity. Kalirajan (1989 and 1991) chose the variables representing farmers' educational status and socio-economic status in studying agricultural efficiency in some developing countries. The socio-economic status in Kalirajan's analysis referred to tenureship, access to credit and motivation in farming (represented by off-farm income). In a study of the effects of economic reforms on Chinese agricultural development, Lin Yifu (1992) considered the contributions of the HRS, the ratio of the price index of agricultural products to manufactured input prices, the multiple cropping index and the percentage of non-grain crops to the total factor productivity growth. This study considers four factors: changes in grain prices and material costs, the development of rural enterprises, the increase in farmers' income and changes in household grain sown areas. The main reason for including these variables is that they have been dynamic factors which influenced the overall development of the rural economy during the reform period. This section specifies the proxies reflecting the changes in these factors. The sources of the data to be used in the analysis are also clarified.[5]

1) The ratio of grain price to material costs

Many previous studies have pointed out that changes in grain and producer goods prices have had a significant influence on grain production during the reform period (Sicular, 1988b; Jin Hehui, 1990; Ke Bingsheng, 1992; Zhou Zhangyue, 1993; Watson, 1994b). In general, farmers' grain output responds positively to increasing grain prices and negatively to increasing producer goods prices. The relative changes in these two aspects are important in determining the profits that farmers' can gain for a given amount of output. A number of scholars, such as McMillan, et al, (1989) and Lin Yifu (1992), have looked directly at the impact of relative prices on the total factor productivity of agricultural production for the country as a whole. They found that increasing agricultural product prices had a positive effect on total factor productivity and that increasing producer goods prices had a negative effect. This study examines specifically the effect of changes in grain price and material costs on the total factor productivity of respective grain crops at the farm household level.

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[5] The study does not include the HRS as an independent variable in the model. This is mainly because of the constraint of data. As the HRS is the foundation on which the factors considered in the model act, the effect of the HRS on total factor productivity is captured by the factors analysed.

In the regression, the ratio of average grain price to material costs per unit of output is taken as a variable to reflect the changes in the average returns that farmers receive per unit of output. The data used are from the SPB household survey. In the survey, the average grain price is calculated as the weighted average of the state purchase prices and the free market prices that households received for selling grain.[6] The average material costs are, in turn, the weighted average price of producer goods paid by farmers at the state and the free markets.

It should be pointed out that the relative prices of grain to non-grain crops can also affect farmers' grain production and consequently total factor productivity. Farmers are in favour of the crops which have higher profits. Many studies have considered these relative prices from a qualitative perspective or based on themselves empirical cases. Systematic studies of this issue covering all the provinces, however, have often been constrained by the complex range of non-grain crops planted in different provinces. For example, in the Huang-Huai-Hai Plain, the major non-grain crops are cotton and peanuts, whereas in the southern provinces, sugar cane and other tropical crops are dominant. As the prices for these crops vary significantly, it is difficult, if not impossible, to make a systematically quantitative analysis of the relative prices of grain to non-grain crops among provinces. Mainly for this reason, the following analysis will not directly discuss the effects of relative prices on total factor productivity. However, these effects will be indicated in the text when analysing the effects of other factors.

[6] In the survey, the price for the grain consumed by farmer households is measured at the state quota price.

2) The development of rural enterprises

The rapid development of rural non-agricultural sectors has brought about dramatic changes in the overall structure of the rural economy, and hence, the socio-economic environment in which farmers are working. There is much debate about the effects of the development of rural enterprises on the total factor productivity of grain production, with both positive and negative consequences identified. Some analysts believe that the development of rural enterprises is favourable to grain production, as labourers can be absorbed by rural enterprises, thereby increasing the productivity of agricultural labour and farm scale. This is conducive to a rise in the efficiency of production (Zhu Xigang, 1991; Liu Yuguang and Song Peiqin, 1991). Scholars with a negative view argue that since returns in the grain sector are generally lower than those in rural enterprises, farmers are attracted towards enterprises, and the productivity is adversely affected by poor management and a lack of motivation to produce grain (State Council, Centre for Rural Development Studies, 1990; Lei Qiquan, et al, 1990; and Wu Jingying, 1993). These two opposing opinions both claim to be supported by empirical observations. This study will clarify the validity of these two arguments.

The variable indicating the development of rural enterprises is the ratio of the gross output value of rural enterprises to the rural social gross output value. The definition of rural enterprises was specified in Chapter 3. It refers to all the enterprises run by townships, villages, cooperatives and individual farm households in the sectors of rural industry, construction, transport and services. The rural social gross output value, according to the State Statistical Bureau, is defined as total gross output values in all sectors in rural areas, excluding the output from the enterprises located in rural areas but owned by governments at county levels and above. The definition of the rural social gross value is relatively consistent over time, which avoids the confusion often occurring in the official statistics due to changes in the scope and definition of statistical data during different periods.

Over the years, the ratio of the gross output value of rural enterprises to the social gross output value has increased substantially. This indicates a faster development of rural enterprises than all other rural sectors as a whole. In fact, during the reform period, one of the remarkable successes in the rural economy has been the rapid development of rural enterprises. The ratio, to a large extent, reflects the relative development of rural enterprises with reference to the overall development of the rural economy.

In the regression, the data for the provincial gross output value of rural enterprises are from the *Chinese Agricultural Yearbook* (ECCAY, *ZNN*, 1982-1991). The data for the rural social gross output value are from the *Chinese Statistical Yearbook* (SSB, *ZTN*, 1982-1991).

3) Average income per capita

Between 1981 and 1990, farmers' average net income increased substantially. As the level of income determines farmers' capacity to accumulate and the potential for capital investment, farmers' production behaviour will be influenced. This will have an impact on total factor productivity.

In the analytical model, the average net income per capita in different provinces is included as an independent variable. The data for 1981 and 1982 are from the *Chinese Agricultural Yearbook* (ECCAY, *ZNN*, 1982, p.91 and 1984, p.191). Other data are from the *Chinese Statistical Yearbook* (SSB, *ZNTN*, 1985, 1988 and 1991). The figures are deflated to 1978 constant prices (using the price index of rural retail goods).

4) Household grain sown area-- an indicator of farm scale

The issue of farm scale is one of the major concerns in the study of production efficiency. Given the small size of household farms in China, increases in grain output have long depended on increasing inputs into the fixed or even declining arable land area.[7] Most scholars believe that the small household farm land has been a barrier to improving total factor productivity (Yi Zhishen, et al, 1990; Wu Zhaocai and Wang Dexiang, 1990; Zhu Xigang, 1991; Fu Weiqun, 1992; Li Qing and Ding Yuankang, 1994). This study examines the effect of household average grain sown areas of wheat, rice and corn on changes in total factor productivity. The data for household average grain sown areas in each province are from the SPB household survey.

It may be worthwhile to clarify the difference between the concept of the effect of economies of scale of farm size on total factor productivity and the concept of the returns to scale in the estimation of production functions. As Thomas explained, the returns to scale implied by a production function depend on the response of output to an equiproportionate change in all inputs. Depending on whether the proportional changes in output is less than, equal to, or greater than, unity, equiproportionate increases in inputs will lead to decreasing, constant, or increasing returns to scale (Thomas, 1993, p.297). The economies of scale of farm size in this study refers to the situation when the available labour and capital can be used more efficiently with an increased quantity of land. In this case, the addition of another unit of land

[7] Where there is surplus labour, however, the marginal productivity of labour input is very small. Further increasing labour input is not likely to generate an extra output.

would "make all units more productive than they were previously" (Lipsey, et al, 1982. p.223).

8.3 The Analytical Model and the Estimation Results

8.3.1 The Model Specification

Based on the data specification in the previous section, an OLS regression with one-way fixed effects model is established as follows:

$$Ln(TFPI_{it}) = A_i + a_1 Ln(P_{it}) + a_2 Ln(I_{it}) + a_3 Ln(E_{it}) + a_4 Ln(S_{it}) \qquad (8.1)$$ [8]

TFPI is the total factor productivity index estimated in Chapter 7.[9] *P* is the ratio of the average grain price to the material costs per unit of output.[10] *I* is farmers' average net income per capita measured in yuan and adjusted to 1978 constant prices. *E* is the ratio of the gross output value of rural enterprises to the rural social gross output value, indicating the development of rural enterprises and structural changes in rural economies. *S* is the

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[8] The author is aware of the effect of the relative price between grain and non-grain crops on grain production. In the model, this is not included because of the complexity of non-grain crops in terms of kinds and prices in the SPB survey.

[9] In calculating the total factor productivity index, the effect of weather fluctuations on the figures has been excluded. It is, therefore, no longer included in this regression.

[10] Some scholars, such as Jin Hehui (1990) and Tian Weiming (1990) believe that farmers make their production decisions according to the grain price of the previous year. Hence, they used one year lagged price figures in estimating the impact of the price on grain production. However, due to the great varieties of grain crops, the different sowing seasons and the multiple cropping systems, the above approach may not be appropriate. For example, winter wheat is planted in October and harvested in the following summer. In the double or triple cropping areas, the announcement of the state price could be at any time in the agricultural seasons. For this reason, farmers would be more likely to make their production decision according to the average price at the time when the decision is made. It is, however, also possible that farmers' production decisions may also be influenced by their expectation of prices in the following year. Despite acknowledging this influence, the study of the effect of anticipated prices on grain production is constrained by the lack of data.

average sown areas of the respective grain crops of production teams (1981 and 1982) and individual households (1983 onwards) measured in *mu*. Subscripts i and t denote the i^{th} province at year t. A_i, a_1, a_2, a_3 and a_4 are parameters to be estimated.

The previous analysis has shown that the growth pattern of grain output and total factor productivity was uneven during the period studied. There are two distinct sub-periods: 1978-1984 and 1985-1990. During these two sub-periods, total factor productivity of grains performed quite differently. The following regression is, therefore, separated into two sub-periods. The purpose of this process is to identify the major factors responsible for the changes in total factor productivity during the two sub-periods.

8.3.2 Report on the Results

The provinces included in the regression are the same as the provinces in the estimation of production functions in Chapter 6. For wheat and rice, there are 20 provinces, and for corn, 19 provinces. The time periods under investigation are 1981 to 1984 and 1985 to 1990. The estimated results for wheat, rice and corn are reported in Table 8.1. The estimation for the period as a whole is presented in Appendix 8.A for reference.

Table 8.1 shows that for wheat, rice and corn, the values of R^2 are all over 0.5, indicating that the independent variables in the model have explained a large part of the variations in the changes in total factor productivity of the respective grain crops during the period studied. The model, therefore, has a reasonably good fit.

Table 8.1. Estimates of The Variables Influencing Changes in Total Factor Productivity of Wheat, Rice and Corn

(One way fixed effects estimation)

Variables	Wheat (I)*	Wheat (II)	Rice (I)	Rice (II)	Corn (I)	Corn (II)
Ratio	0.358	0.447	0.383	0.203	0.433	0.240
	(4.296)	(6.766)	(3.256)	(3.013)	(9.541)	(5.525)
Income	0.207	-0.014	0.335	-0.016	0.201	-0.047
	(6.245)	(-0.759)	(7.592)	(-0.390)	(6.532)	(-0.595)
Rural enterprises	0.028	-0.136	0.005	-0.127	-0.111	0.033
	(0.684)	(-2.723)	(0.051)	(-2.919)	(-1.539)**	(1.477)**
Sown area	-0.014	-0.014	0.035	0.036	-0.011	-0.012
	(-0.130)	(-0.248)	(2.042)	(2.221)	(-0.402)	(-0.530)
R^2	0.717	0.694	0.701	0.559	0.750	0.639
F	9.005	9.476	7.980	8.667	13.721	21.606
Hausman statistic	10.810	5.640	8.621	7.244	15.109	7.360
Chow test	13.056		10.890		14.610	

* (I) and (II) represent the two sub-periods: 1981-1984 and 1985-1990, respectively.

** Significant at the 20 percent significance level.

The regression considered the two sub-periods separately. The result shows significant differences in the values of the coefficients. The Chow test values are significant for all the three grain crops, implying the differences in the regressions between the two sub-periods. This result suggests that variables affecting changes in total factor productivity were not identical during the two sub-periods. Therefore, the analysis of the causes of the changes in the total factor productivity of grain production needs to take into consideration the variations during the different sub-periods. This is particularly important when making a judgement of the effect of a variable on total factor productivity changes. Without stating the period under investigation, the judgement will not make much sense and the conclusion could be misleading. The regression result also shows that there are variations among different grain crops, suggesting the importance of specifying the location and types of crops when making any judgement. Referring to the debate over the effect of the growth of the rural enterprises on the total factor productivity of grain production mentioned earlier, it is clear that both opinions can only be judged with reference to the period studied, areas covered and crops considered.

In the regressions, the coefficients of some variables are statistically insignificant. This is partly caused by the multicollinearity among the explanatory variables. This is, however, to be expected because the changes in income are closely related to the changes in prices and the development of rural enterprises. The following analysis will investigate the interactions of these factors and explore their aggregate effects on the changes in total factor productivity.

8.4 Analyses of the Results and the Economic Implications

8.4.1 Effects of Prices, Incomes and the Development of Rural Enterprises on Changes in Total Factor Productivity Prior to 1985

The estimation results show that during the first sub-period, between 1981 and 1984, the coefficients of the ratio of grain price to material costs were statistically significant and positive for wheat, rice and corn. This meant that increasing the net returns per unit of grain could stimulate farmers' production efficiency and decreasing the net returns would have an opposite effect.

Table 8.2 Ratio of Average Grain Price to Material Costs Per Unit of Output for the Respective Grain Crops, 1980-1990

(Average Grain Price/Material costs)

	wheat	rice	corn
1980	1.84	2.55	2.54
1981	1.94	2.55	2.50
1982	2.12	2.64	2.47
1983	2.13	2.68	2.55
1984	2.72	3.30	3.13
1985	2.45	3.27	3.13
1986	2.60	3.36	3.58
1987	2.37	3.24	3.10
1988	2.19	3.08	3.06
1989	2.24	3.00	3.06
1990	2.08	2.87	2.61

Source: Data for 1980 are from the SPB, *ZWN*, 1989, p. 73. Data for other years are from the SPB, *QNCSDZH*, 1981-1991.

Table 8.2 shows that during the early years of the reforms, the ratio of grain price to material costs increased steadily and experienced a big jump in 1984. This is most likely related to the way the state purchase price was set. Before 1984, the state paid different prices for grain purchase, including the quota price, the above-quota price and the negotiated price (Colin Carter and Zhong Funing, 1988, p.40). The quota price was the lowest and the negotiated price was the highest. Meanwhile, the reforms in the marketing system allowed farmers to sell their surplus grain on the free market after they fulfilled the state grain quota. The free market price was usually higher than the state purchase price. In this case, the average price farmers could receive depended on the quantity they sold. After fulfilling the fixed grain quota, if farmers could sell more, they would receive the above-quota price. If they still had more to sell, they would be paid at the negotiated price or at the free market price.[11] As a result, the more the farmers could sell, the higher the

[11] In the early years of the reforms, the quantity of grain sold on the free market was relatively small compared with the state purchase. According to the author's estimation in another study, grain sold in the free market was less than 1/10 of the total traded grain in

average price they could receive. This partly explained the significant increase in the ratio of the grain price to material costs in 1984 as shown in Table 8.2. In that year, the record harvest led to a large increase in the grain sold to the state at the above-quota price. It seems clear that the pricing system during the early years of the reforms provided incentives to farmers to produce more grain and to sell more to either the state or on the free markets. This would have encouraged farmers to improve production efficiency.

The estimation shows that during the early years of the reforms, the coefficients of incomes are statistically significant and have positive signs for all the three grain crops. This result indicates that increasing farmers' incomes was conducive to improving the total factor productivity of grain production during the earlier sub-period.

The positive relationship between income and total factor productivity during the early 1980s can be partly explained by the fact that grain production was the major source of farmers' income at the time. The motivation to increase incomes stimulated farmers' enthusiasm to increase grain output when grain production was profitable and the ratio of grain price to material costs per unit output was increasing. According to the SPB survey, in 1981 the profits[12] per *mu* of wheat, rice and corn were 7.88 yuan, 22.58 yuan and 15.66 yuan, respectively. This is significantly higher than the profits in 1978, which were -0.52 yuan, 8.77 yuan and 2.47 yuan, respectively (SPB, *ZWN*, 1990, p.72). Given the fact that grain production accounted for a large proportion of households' incomes, it is not surprising that the profits

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1980 (Yang Hong, 1991). Because of the small proportion of the free market trade, the average price farmers could receive was dominated by the state purchase prices.

[12] The profits refer to the returns after deducting material and labour costs.

after 1979 stimulated farmers to increase marginal grain output.[13] This would also encourage farmers to manage their production more efficiently.

Table 8.3 Changes and Sources of Farmers' Average Net Incomes Per Capita, 1978-1990 (Constant prices)

(yuan/per capita)

	Net income	Agricultural income[1]	Non-agricultural income [2]	Non-production income[3]
1978	133.57	122.9 (85.0)[4]	9.39 (7.0)	10.7 (8.0)
1979	157.03			
1980	167.71	138.4 (78.2)	15.5 (8.8)	23.1(13.0)
1981	202.61			
1982	240.37			
1983	271.58	194.4 (71.6)	44.8 (16.5)	32.3 (11.9)
1984	303.05	213.5 (70.5)	55.2 (18.2)	34.4 (11.3)
1985	311.67	206.8 (66.3)	67.6 (21.7)	37.3 (12.0)
1986	313.66	206.5 (65.8)	70.8 (22.6)	36.3 (11.6)
1987	319.22	207.6 (65.0)	81.1 (25.4)	30.5 (9.6)
1988	317.23	201.2 (63.3)	86.4 (27.2)	29.6 (9.5)
1989	297.25	183.7 (61.8)	83.3 (28.0)	30.3 (10.2)
1990	304.83	192.7 (63.2)	80.9 (26.5)	31.3 (10.3)

Note: 1. Agricultural income here refers to the income from broad agriculture, including crop farming, animal husbandry, fishery, forestry and sideline production.
2. Non-agricultural production income refers to the income from rural enterprises, including rural industry, construction, transport and services.
3. Non-production income includes income in cash and in kind sent back by household members working outside of their home town, income from public funds and collective accumulation, and income from the state government for poverty and disaster reliefs.
4. Figures in brackets are the shares of each source in the total income.

Source: Data for 1978-1982 are from SSB, *ZTN*, 1983, p.499. Data for 1983-1987 are from SSB, *ZTN*, 1988, p.823. Data for 1988-1990 are from SSB, *ZTN*, 1991, p.295.

Table 8.3 shows that between 1978 and 1984, farmers' average net income more than doubled. Although the share of agricultural income in the total net income decreased constantly, it increased in absolute terms.

[13] According to the SPB survey data, for rice farmers, the increased output could earn up to 120 yuan for each household. The survey data show that the average rice yield increased by 57 kg/mu during this period, whereas the total production costs were rather stable. The increased yield, therefore, created approximate 20 yuan/mu. According to the survey, the average household rice paddy was 6 mu, the total increase in the net income from increased rice output was, therefore, roughly 120 yuan.

According to the official statistics, in 1980, the gross output value of grain production accounted for about 50 percent of the total gross output value of agricultural production (the broad concept) (SSB, *ZNTN*, 1988, p.27 and p.39). It is reasonable to believe that, of the increased income, the contribution of grain production accounted for a large proportion.

The effect of increasing grain incomes on total factor productivity was particularly strong when the opportunities outside agricultural production were still rare in the early 1980s. For a long time before the reforms, rural non-grain sectors (except for a few industrial raw crops, such as cotton and oil-bearing seeds) were generally restricted under the policy of grain self-sufficiency. When the rural reforms began in the late 1970s and the early 1980s, grain production was the predominant sector in the rural economy. Increasing grain output was an important means of increasing households' incomes. Total factor productivity could improve as the result of the motivation to increase incomes. This is the reason for the positive relationship between increasing incomes and improving the total factor productivity of grain production as shown in the regressions.

The effect of the development of rural enterprises was rather complicated. The statistical test shows that for wheat and rice, the coefficient was statistically insignificant. For corn, it is only significant at the 20 percent level and has a negative sign. The reliability of any conclusion based on this result may be poor. Nevertheless, if we examine changes in farmers' food grain consumption during the first sub-period, the differing impact of the development of rural enterprises on the total factor productivity of the respective grain crops seems reasonable.

Table 8.4 Changes in Farmers' Food Consumption, 1978-1990

(kg/per capita, year)

Item	Grain*	Vegetables	Edible oil	Meat	Eggs
1978	248(123)**	142	1.96	5.76	0.80
1979	257(140)	131	2.38	7.50	0.90
1980	257(163)	127	2.49	7.75	1.20
1981	256(173)	124	3.13	8.71	1.25
1982	260(193)	132	3.43	9.05	1.43
1983	260(197)	131	3.53	9.97	1.57
1984	267(209)	140	3.97	10.62	1.84
1985	257(209)	131	4.04	10.97	2.05
1986	259(212)	134	4.19	11.79	2.08
1987	259(211)	130	4.69	11.65	2.25
1988	260(211)	130	4.76	10.71	2.28
1989	262(213)	133	4.81	11.00	2.41
1990	262(215)	135	5.17	11.34	2.41
1991	255(214)	127	5.65	12.15	2.73

* Direct grain consumption.
** Data in brackets are the fine grain consumption.

Source: Data for 1978-1984 are from SSB, *ZTN*, 1985, p.573. Other data are from SSB, *ZTN*, 1991, p.303.

The initial reforms started in the late 1970s. At that time, low incomes and poverty were widespread in rural areas. It was not surprising that when farmers were allowed to manage their own production, the immediate task for them was to produce more food to improve their own consumption. As shown in Table 8.4, this was characterised by changes in the structure of the direct food grain consumption rather than the total quantity. Between 1978 and 1984, the total direct food grain consumption per capita only increased from 248 kg to 267 kg. The fine grain consumption per capita increased from 123 kg to 209 kg. The coarse grain consumption decreased from 125 kg to 58 kg. As the major component of coarse grain, the direct consumption of corn would have decreased substantially. This implies that driven by the eagerness to improve food consumption, farmers were more interested in increasing fine grain output and had less enthusiasm to produce corn. The negative coefficient of the development of rural enterprises in the estimation for corn may imply that farmers preferred to use surplus capital, if any, to develop rural enterprises.

8.4.2 The Roles of Prices, Incomes and Rural Enterprises in Grain Production after 1985

During the second sub-period, the coefficients of the ratio of grain price to material costs were still positive and significant for all the three grain crops. This implies that during this period, total factor productivity was lowered because of the decrease in the ratio as shown in Table 8.2.

The decrease in the ratio of grain price to material costs was mainly the result of the rapid increase in the prices of producer goods. Between 1985 and 1990, the price for agricultural producer good increased by 57.7 percent measured at current prices (SSB, *ZTN*, 1991, p.242). Grain production became less profitable than before and also in comparison with many other sectors. This would have affected farmers' enthusiasm for grain production and worked against the improvement of total factor productivity.

The estimated results show that during the second sub-period, the coefficient of income became statistically insignificant for all the three grain crops. This feature implies that during the second sub-period, the increase in income had little direct effect on the total factor productivity of grain production. This is expected because after 1985 the income from agricultural production decreased both proportionally and absolutely. The increased income was from the non-agricultural sources, in particular rural enterprises (see Table 8.3).

The lack of enthusiasm in producing grain production during the second sub-period is also related to the fact that the eagerness to improve direct food consumption was fading. By 1984, most Chinese rural areas had initially solved the food shortage problem.[14] This may be seen in Table 8.4, which shows that the consumption of food grain and vegetables - the basic food for farmers - has not changed significantly since then. The reasonably sufficient food consumption after 1985 left room for farmers to consider the relative profits among different sectors rather than merely relying on increasing grain output.

It needs, however, to be pointed out that the increase in incomes during the early years of the reforms also had a profound effect on the overall rural economic situation in the later years. The increased incomes allowed farmers to accumulate capital, which was crucial for farmers to undertake non-agricultural activities, in particular rural industries. Between 1978 and 1984, farmers' incomes more than doubled. This rapid increase in incomes provided the foundation for the later years' development of rural enterprises. By the mid 1980s, farmers' economic conditions were ready for them to direct production efforts to the more profitable sectors. When the government implemented the new marketing policies in 1985, farmers responded by rapidly transferring their accumulated capital to non-grain sectors.[15]

The estimation result shows that during the second sub-period, the coefficient of rural enterprises has a negative sign for wheat and rice. For

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[14] This was officially claimed by the government in 1984.

[15] It is reported that farmers in the crop farming sector had the lowest average incomes, whereas in the industrial and transport sectors they had the highest (Hu Jilian, 1989, p.20). As the most important component in the crop farming sector, grain production is also less profitable compared with other crops. According to a household survey, since 1985, the profits from grain production have been the lowest among all the crops (Wu Yiping and Dai Qiang, 1992, p.50)

corn, it is positive but only significant at the 20 percent level. The value of the coefficient is also small. It indicates that during the second sub-period, the development of rural enterprises had negative effects on the total factor productivity growth of wheat and rice. For corn, the development of rural enterprises seemed to have a positive effect. This feature is different from the situation during the first sub-period. It suggests that farmers' grain production behaviour changed during the different stages of rural economic development.

The negative effect of the development of rural enterprises on the total factor productivity of wheat and rice may be related to the generally high opportunity costs in grain production. During the second sub-period, total grain output increased slowly, and the ratio of grain price to material costs declined. The increased incomes were mainly from the activities outside of grain production. Farmers were attracted by the relatively high profits in rural enterprises and became less interested in grain production. It is reported that in some developed areas, grain production became a sideline occupation (Yang Tao and Cai Fang, 1991). Farmers tended to put less effort into grain production, which resulted in the negative effects of the development of rural enterprises on total factor productivity of wheat and rice.

This result explained partly the generally poor performance of grain production in the southeast and central provinces during the second sub-period. The rapid development of rural enterprises in these areas provided more opportunities outside of grain production. Farmers were more reluctant to produce grain. In contrast, in the areas where rural enterprises were less developed, fewer opportunities were available for the farmers. Increasing grain output was still a major source of increasing incomes. For this reason, farmers in these areas may have cared more about their grain production.

This result supports the hypothesis made in earlier chapters that there is an inverse relationship between the development of rural enterprises and total factor productivity during the later 1980s. As further evidence, in 1989 and 1990 when the development of rural enterprises suffered from overall austerity, the total factor productivity of wheat and rice production had a significant recovery.

The coefficient of rural enterprises for corn production was positive, though the significance level was low and the value was small. This may be explained by the fact that for rural households, with the increase in incomes, the demand for meat and dairy products increased. This required an increase in feed grain, which may provide an incentive to produce corn and to improve the efficiency of production. The availability of new technology for corn production during the late 1980s reinforced this incentive (see Chapter 5).

To sum up, the uneven course of change in the total factor productivity of grain production was closely related to the farmers' goal of improving food consumption and increasing incomes. During the early 1980s, the implementation of the HRS enabled the farmers to organise household production more efficiently in comparison with the People's Commune system. The motivation to improve food consumption and increase incomes worked in the same direction and reinforced each other, which brought about a significant improvement in total factor productivity during the early years of the reform, mainly through the better utilisation of the accumulation in the previous period. Although the stagnation in later years was partly inevitable because of the depletion of the earlier accumulation, the conflict between increasing incomes and increasing grain output was also responsible, as the relative price was in favour of rural enterprises.

8.4.3 Household Average Grain Sown Areas and Economies of Scale

The small scale of the household farm in China has often been considered to be a reason for the low level of total factor productivity in grain production. Hence, increasing farm size is believed to be conducive to improving total factor productivity, whereas decreasing farm size would result in the opposite effect. The estimated results using the SPB survey data show some variations among different grain crops. For rice production, the positive and significant coefficient of the household sown area during both sub-periods seems to support the above opinion. For the other two grain crops, wheat and corn, the coefficient is statistically insignificant.

The statistically insignificant coefficient of sown area for wheat and corn is not what was expected. Two reasons may be responsible for this result.

Firstly, the extremely small household sown area could mean that a small change in household farm size may not be able to achieve economies of scale. According to Zhu Xigang's study, with current technology the suitable farm size for each household should be around 20 *mu* (Zhu Xigang, 1991, p.15). According to another study, the threshold scale of grain sown areas for individual households was about 10 *mu*. At this threshold scale, farmers involved in grain production can gain similar incomes to those in other sectors. Below this scale, household incomes were lower than in other sectors. Farmers have to undertake other activities while maintaining a simple level of grain re-production (*jiandan zaishengchan*). Household operation, in this circumstance, is inefficient (Lei Qiquan, et al , 1990, p.56). The SPB survey data show that in 1985 the average sown areas of surveyed households were only 5.1 *mu*, 5.1 *mu* and 4.2 *mu* for wheat, rice and corn, respectively. These figures are the average sown areas of each household. For each household, however, the contracted land is often separated into several plots and scattered around the village. According to one source, average household land after the implementation of the HRS was 8.35 mu, which was separated into 9 pieces (Lu Qian, 1990, p.21). Apparently, the average household grain sown areas in the survey were far below the threshold scale. The statistically insignificant coefficient of sown area of wheat and corn may imply that increasing sown areas below a certain level is not always able to achieve the economies of scale.

The second reason for the insignificant coefficient of sown area for wheat and corn is perhaps associated with the different arable land endowment in different provinces. The SPB survey shows that for wheat and corn, the average household sown area varied significantly. A relatively large size is found in inland and remote provinces, such as Xinjiang, Qinghai, Neimenggu, Gansu and Heilongjiang. In southeast and coastal provinces, the average household grain sown area is small. For example, the average household wheat sown area in Heilongjiang and Neimenggu was about 10 mu and 20 mu, respectively. Whereas in Hebei and Shandong, the average wheat sown areas were approximately 5 *mu*. Empirical observation shows that the level of total factor productivity in the former two provinces was lower than that of the latter two. This can be seen from the different values of the fixed effects in these provinces shown in Table 6.1. Increasing wheat sown areas in Heilongjiang and Neimenggu may not induce economies of scale. A similar situation can be seen in corn production. The heterogeneity of farm size in different provinces may cause difficulties for examining the effect of economies of scale. This could have been partly responsible for the statistically insignificant coefficient of household sown area for wheat and corn. Compared with wheat and corn, the average household sown area of rice varies little among different provinces, which may allow the regression to capture the effect of changes in household rice sown area on total factor productivity.

Because of the above two reasons, the estimation result is not sufficient to make a conclusive judgement on the direct effect of household farm size on the total factor productivity of wheat and corn using the SPB survey data. However, the positive and statistically significant coefficient of household sown area for rice may imply that a similar relationship can be expected in wheat and corn production.

It needs to be pointed out that apart from the direct effect of farm size on total factor productivity through the economies of scale, farm size also has an indirect effect on total factor productivity through its effect on household incomes. As discussed earlier, the negative effect of the development of rural enterprises on total factor productivity in the late 1980s was closely related to the relatively low net incomes in the grain sector in comparison with rural enterprises. Although the low state grain purchase prices and the increasing producer goods prices were direct reasons for the stagnation of farmers' income from grain production, the extremely small household farm size is also a constraint. This situation can be demonstrated using the simple mathematical calculation shown in Table 8.5.

According to the standard labour day measurement, with the small household sown area the total labour days needed in producing wheat, rice and corn were less than 100 days for each household. Supposing a labourer can work 200 days a year, less than a half labourer is needed to complete the work in operating the household grain sown area. Even taking multiple cropping, which on average is 150.6 percent (ECCAY, *ZNN*, 1991, p.293) into consideration, the labour needed for the on-farm work is still limited for individual households. The official statistic shows that the average number of household labourers was 2.94 in 1990 (SSB, *1991*, p.244). Obviously, the small area of farm land cannot fully utilise household labour, which results in low labour productivity in grain production and consequently low household incomes. This is one of the reasons why the increase in farmers' incomes becomes less reliant on grain production, and why there is an increasing tendency for household labourers and capital to shift to non-grain sectors, in particular to rural enterprises. This can generate indirect effects on total factor productivity, although the direction of the effects depends on whether or not this shift can make grain production more efficient for individual households.

Table 8.5 Household Average Sown Areas, Labour Inputs and Net Returns of Grain Production, 1990

	Wheat	Rice	Corn
Average sown area of each household (mu/household)	4.95	4.54	4.53
Labour input required for each household (standard labour days)	69.30	93.52	78.37
Net return per *mu** (yuan/per mu)	80.52	172.27	109.63
Net income from grain for each household (yuan/household)	398.57	782.10	496.62

* Net return refers to the cash returns after deducting material costs.

Source: Calculated by the author based on the SPB survey. Xinjiang is excluded in the calculation of wheat and corn as the farm size in this province is strongly influenced by the state farms, which are much larger than ordinary households.

8.5 Conclusions

This study applied the log-linear regression model to examine the effects of changes in the ratio of grain price to material costs, the development of rural enterprises, changes in farmers' incomes and household sown areas on the growth pattern of total factor productivity of grain production.

One of the important findings is that the roles of some variables affecting total factor productivity were not the same during the early years of the reforms as in the later years. This result underlines the significance of considering the two sub-periods in analysing factors responsible for the growth pattern of total factor productivity. In addition, it is also found that there are variations between different grain crops in responding to the respective variables. This result suggests a need to specify the period studied, the location of the area and the crops considered when making economically meaningful judgements about the effect of different factors on changes in total factor productivity.

In general, during the early years of the reforms, the total factor productivity of grain production responded positively to the increase in the ratio of grain price to material costs and the incomes. As grain production was the most important income generator when other sectors were not developed, farmers devoted a great deal of attention to increasing marginal grain output through more efficiently organising their production and utilising the available resources.

During the second sub-period, the ratio of grain price to material costs declined. The increased incomes were mainly from non-agricultural activities, in particular rural enterprises. Farmers were attracted by the higher capital returns in rural enterprises and had little enthusiasm to produce grain. This tendency became particularly strong after farmers had solved food problems. This led to a generally poor level of management of grain production.

The food consumption situation of rural households has been an important dynamic behind the growth pattern of the total factor productivity of different grain crops. In the early 1980s, increasing fine grain consumption was the main trend and provided incentives for farmers to produce rice and wheat. In the late 1980s, direct fine grain consumption was rather stable whereas the consumption of meat and dairy products continuously increased, resulting in an increasing demand for corn. This, together with the available new technologies, provided incentives for corn production and was conducive to the improvement in total factor productivity.

Finally, the disparities in provincial total factor productivity and the variations amongst the individual grain crops in response to the different factors imply that in China, due to great diversities of natural and socio-economic conditions, one factor may be influential in one area and for one crop over a certain period but less influential for another. This result suggests that grain development policies should be tailored according to the situation for different grain crops in different areas.

Appendix 8.A

Table 8.A Estimates of Variables Influencing Changes in Total Factor Productivity, 1981-1990

Variables	Wheat	Rice	Corn
Ratio	0.396 (8.457)	0.350 (4.230)	0.359 (12.854)
Income	0.131 (4.897)	0.214 (4.759)	0.146 (6.598)
Rural enterprises	-0.006 (-0.252)	0.036 (0.049)	0.025 (1.559)
Sown area	0.020 (0.379)	0.039 (2.189)	-0.065 (-0.387)
R^2	0.672	0.689	0.831
F	15.699	18.780	37.469
Hausman statistic	8.642	7.830	7.707

Chapter 9

Production Efficiency and the Role of Provincial Governments in Grain Production

9.1 Introduction

One of the goals of studying provincial total factor productivity is to examine the relative efficiency of grain production in terms of resource (inputs) utilisation. With the progressive decentralisation of central government control and the greater role for provincial governments in grain production management, the issue of relative provincial efficiency has become increasingly important.

In Chapter 5, it was found that the yield of grain crops varies significantly among the producing provinces. Some provinces have a higher yield than others. This, to a large extent, reflects the effect of variations in natural conditions in different producing provinces. Provinces where natural conditions are favourable for the production of a particular crop usually have a high yield. Conversely, in provinces where natural conditions are not so favourable, the yield tends to be low. Given a certain level of inputs, the output is, therefore, higher in the former provinces than that in the latter provinces.

In Chapter 7, it was shown that the yield growth during the period studied was attributed to both the increase in inputs and the improvement of total factor productivity (technology and production management). Chapter 8 revealed that the growth pattern of total factor productivity and farmers' input behaviour were closely related to socio-economic factors, including institutional reforms, marketing and pricing policies, structural changes in the rural economy, and changes in farmers' incomes and food consumption. It was also found that the impact of some of these elements on total factor productivity was dynamic and changed with the progress of the reforms and the development of the rural economy.

The results of the preceding chapters have illustrated clearly that the level of yield in a province at a given moment is determined by the combined effects of natural and socio-economic conditions in the province. The latter effect is through its influence on the level of inputs, technology and production management.

A production function measures the relationship between a set of inputs and output. The variations in provincial yield, caused by variations in natural conditions, the levels of technology and production management will be reflected as shifts of production function curves, represented by the different values of provincial fixed effects in production functions. The production is therefore more efficient in terms of input utilisation in provinces where the value is high, and less efficient where the value is low. Using this norm, the relative production efficiency in different provinces can be determined.

This chapter starts by examining the relationship between provincial grain yield and the level of production efficiency. The purpose is to investigate whether or not the variations in grain yield are associated with variations in production efficiency. This is followed by a discussion of the relative efficiency of provincial grain production in both inter-provincial and intra-provincial dimensions. It is worth pointing out that so far, there are hardly any studies which have addressed this issue explicitly. Yet studying relative provincial efficiency is of practical significance since it provides necessary information for the adjustment of the spatial distribution of grain production so that the national resources can be used most efficiently.

Another issue discussed in this chapter concerns the role of provincial governments in grain production management and the implication for the efficient use of provincial resources. In the preceding chapters, analysis has mainly concentrated on the impact of government policies and the response of grain producers. The role of provincial governments in managing local grain production has not been specified explicitly. Since the reforms began, the progressive decentralisation of grain production management has given provincial governments increasing freedom to make their own production plans and policies. Despite this, it is also true that central government control over grain production remains important and grain prices and markets are still not entirely free.[1]

Yet, decentralisation has been a nationwide trend in all aspects of the national economy. The decentralisation has entrusted provincial governments with the responsibility for provincial economic development. Furthermore, the fiscal and financial reforms since the mid 1980s have created various forms of contract system in defining the share of revenues and budgets between the central and local governments (Cheng Enjiang, 1993; Tsang Shu-ki and Cheng Yuk-shing, 1994). This has led provincial governments to be

[1] After 1991, the tendency towards totally abandoning state procurement of grain has become increasingly strong. In many areas, the practice of freeing grain trade has been implemented. It is reported that starting from 1992, the central government has decided to accelerate the transition from state procurement to market trade. The role of the market, therefore, has increased significantly.

more concerned with their own interests over gains and losses in grain production and trade. It is, therefore, of significance for this study to look at the role of provincial governments in local grain production and to analyse the implications for provincial grain production efficiency in terms of resource utilisation.

The chapter is organised as follows: Section 2 first sets out the values of provincial fixed effects estimated in Chapter 6 and specifies their economic significance in relation to production efficiency. It then investigates the relationship between the level of grain yield and the level of provincial production efficiency. Section 3 examines the relative efficiency among provinces with regard to one kind of grain crop, and within one province with regard to different grain crops. Section 4 analyses the effect of the grain production management system in the 1980s and the early 1990s, and specifies the role of provincial governments in provincial resource utilisation. Section 5 summarises the main findings of the chapter.

9.2 Provincial Production Efficiency and Its Relationship to Grain Yield

9.2.1 The Determination of Provincial Production Efficiency

In Chapter 6, the production functions were estimated with a fixed effects model for wheat, rice and corn. It can be seen that the value of d_i varies among provinces for the respective grain crops (Table 6.1, Table 6.2 and Table 6.3). The different level of the provincial fixed effect d_i, means that given a certain set of inputs, output differs among producing provinces for the respective grain crops. The value d_i, therefore, can be viewed as parametric shifts of the regression function (Greene, 1990, p.485-495). Given the level of inputs, the larger the d_i is, the greater is the output obtainable from such inputs. Hence, the value of d_i represents the production efficiency of a province. With the panel data approach used in this study, the value of d_i in different provinces is determined by the level of technology and production management and the natural endowments (including soil quality, water conditions, topography, temperature and so forth) during the period the data set defines.

9.2.2 The Relationship Between Yield and Provincial Production Efficiency

As discussed earlier, the level of yield is the combined result of inputs, technology, production management and natural conditions. The output attributed to the latter three elements is the gain from production efficiency. The purpose of this section is to investigate whether or not the variations in provincial yield are associated with the level of production efficiency. The judgement is made on the basis of the following consideration: if the level of provincial grain yield has similar spatial patterns as the level of d_i, then it is reasonable to believe that variations in provincial yield are related to the level of provincial production efficiency. The inference is that the high yield provinces have a high production efficiency. Conversely, the low yield provinces have a poor production efficiency. If the yield and the level of production efficiency are inconsistent, then it would suggest that the variations in yield among provinces are mainly the result of different levels of inputs. A high yield is, therefore, not necessarily related to efficiency in terms of resource utilisation, as it could have been achieved from a large amount of inputs.

Figure 9.1 The Relationship Between Wheat Yield and the Level of Production Efficiency for Different Provinces

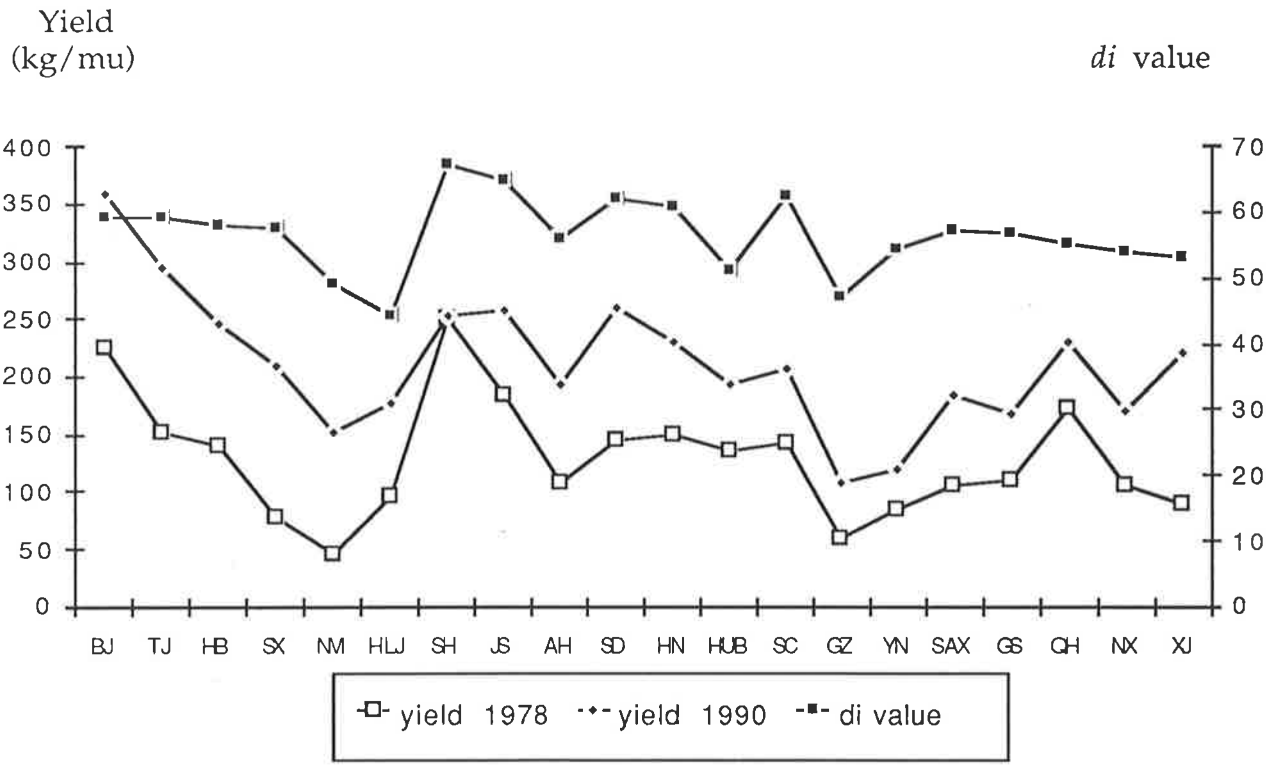

Figure 9.2 The Relationship Between Rice Yield and the Level of Production Efficiency for Different Provinces

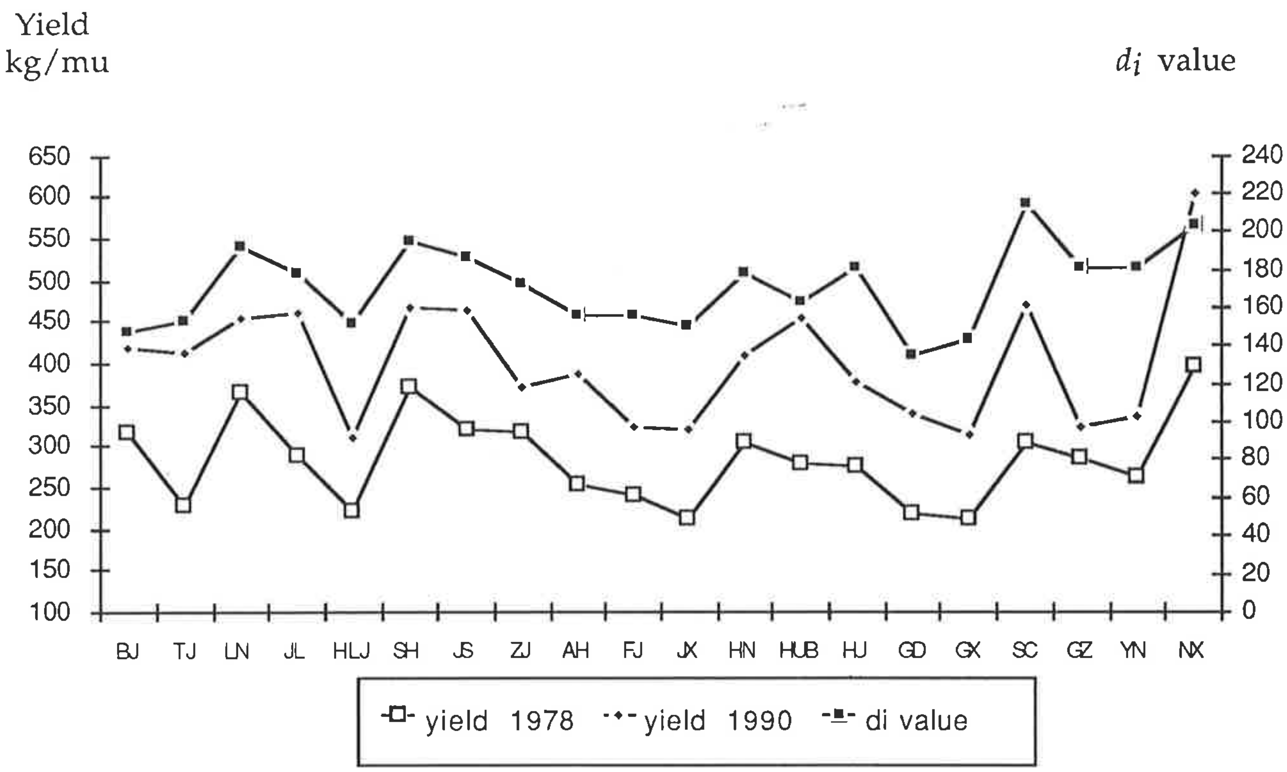

Figure 9.3 The Relationship Between Corn Yield and the Level of Production Efficiency for Different Provinces

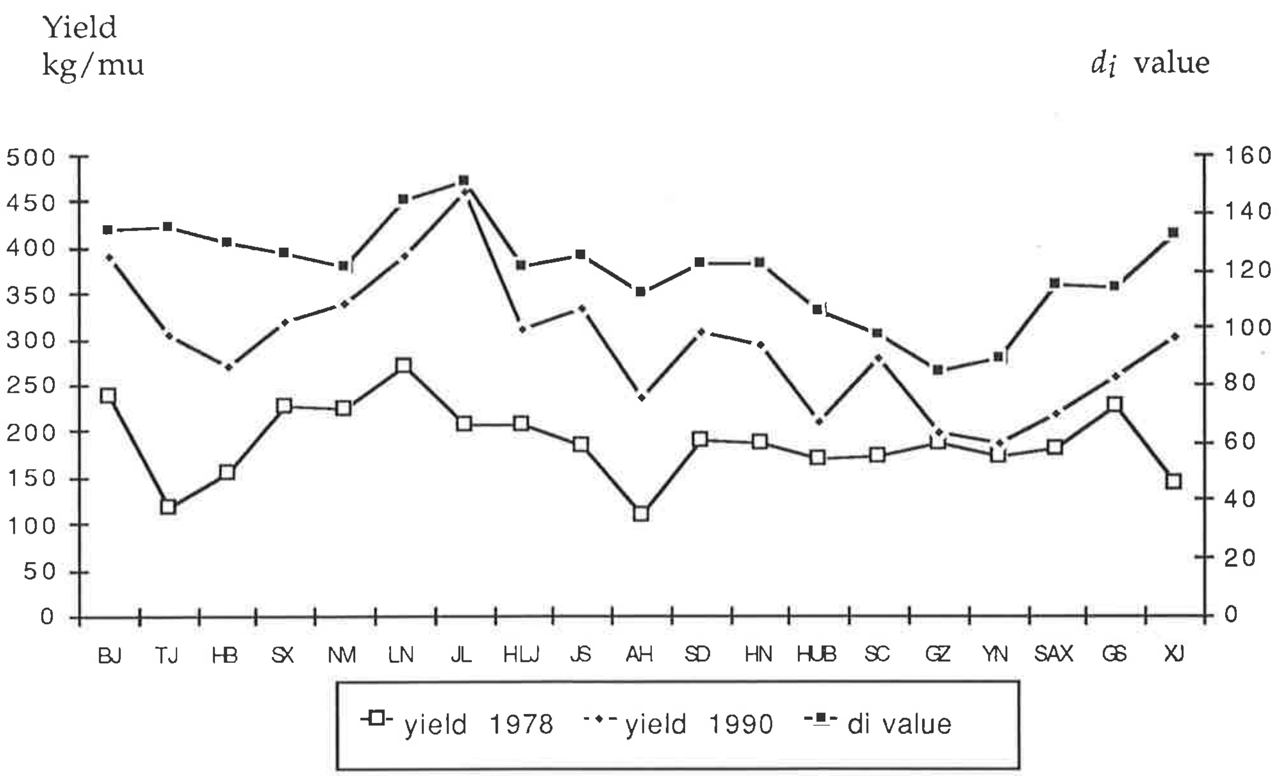

Figure 9.1, Figure 9.2 and Figure 9.3 show the levels of provincial yield of 1978 and 1990 and provincial production efficiency d_i (non-logarithmic value) for wheat, rice and corn. A high consistency between the level of grain yield and the level of provincial production efficiency can be observed. This consistency accepts the hypothesis that the variations in yield among producing areas are closely related to the level of provincial production efficiency. High yield can be partly attributed to the high level of production efficiency and the low yield is, in turn, partly the result of the low efficiency.

Some distinctive features, however, can be seen in the respective grain crops and in the different years.

For wheat and rice production, as shown in Figure 9.1 and Figure 9.2, the spatial pattern of yields in 1978 was more consistent with the spatial pattern of provincial production efficiency. The shape of the two lines has the same trend. In 1990, although the spatial pattern of yield was still consistent with the level of provincial production efficiency, the shape of the yield line was sharper, suggesting increased variations in grain yield among provinces. Taking into consideration that the natural conditions (except weather fluctuations) were generally static during the period studied, the enlarged yield variations would have been mainly the result of uneven progress in technology and production management and the different level of inputs.[2] Despite the enlarged yield variations, the general consistency between yield and provincial production efficiency remained, indicating that the variations in yield were still closely related to the variations in the level of production efficiency in different provinces.

For corn production, as shown in Figure 9.3, the situation was slightly different from wheat and rice production. In 1978, the consistency between the spatial distribution of corn yield and production efficiency was relatively weak in the southwest and northwest provinces, including Hubei, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu and Xinjiang. In 1990, the consistency of the two lines was much more obvious. The situation in 1978 may imply that the levels of technology and production management were generally low for corn production and that there were no significant differences among the

[2] The effect of weather fluctuations is not considered here. This may affect the level of yield for different provinces and in different years. However, the effect of weather fluctuations cannot sufficiently explain enlarged variations of yield among provinces. Therefore, ignoring the effect of weather fluctuations is not likely to affect the conclusion of the analysis.

above provinces. The increased variations in yield in 1990 were most likely the result of uneven paces among different provinces in terms of the application of technology and the efficiency of production management. This point has been raised in the preceding chapters, which show that the major corn producing provinces experienced a significant improvement in total factor productivity.

The general consistency of the spatial distribution of grain yield and provincial production efficiency suggests that for a respective grain crop, high yield provinces were associated with a high level of production efficiency, whereas low yield provinces generally had a low production efficiency. Considering that the level of production efficiency is partly the result of natural conditions, the variations in production efficiency among provinces are almost inevitable. It is therefore important for a province to specialise in producing grain crops for which the province has relatively suitable natural conditions. In this way, the available inputs can be used more efficiently.

9.3 Relative Efficiency in Provincial Grain Production

In studying the relative efficiency of provincial grain production, two dimensions are involved: inter-provincial and intra-provincial efficiency. Inter-provincial production efficiency refers to the relative efficiency of different provinces in producing one kind of grain crop. Intra-provincial production efficiency concerns the relative efficiency within a province where more than one kind of grain crop is produced. The relative level of production efficiency, reflects the comparative advantage of the province in producing the respective grain crops.[3]

[3] Here, the analysis is based purely on the resource utilisation of a province. The transport costs are not considered.

The value of parameter d_i shown in Table 6.1, Table 6.2 and Table 6.3 provides a direct norm for judging the inter-provincial production efficiency of the respective grain crops. The higher the value of d_i, the more efficient is the production. However, the intra-provincial production efficiency cannot be directly judged. For a particular province, even if the value of d_i is relatively low in comparison with other provinces for the same grain crop, the province may still be relatively efficient in producing a grain crop in comparison with producing other grain crops within the province.

Table 9.1 shows the non-logarithmic values of d_i for different provinces. To observe the inter-provincial and intra-provincial production efficiency, the provinces producing respective grain crops are ranked into three levels according to the value of d_i. Inter-provincial efficiency is reflected in the vertical ranking and intra-provincial efficiency is reflected in the horizontal comparison ranking. The numbers in the "( )" brackets stand for the ranking of provincial production efficiency of the respective grain crops, based on the three broad bands. The figures in the "[ ]" brackets are the proportion of sown areas of the respective crops in provincial total grain sown areas. These figures indicate the level of specialisation of the respective grain crops in provincial grain production.

Examining the inter-provincial dimension, it can be seen that the value of d_i varies significantly among provinces (the vertical ranking), representing the differences in the levels of relative efficiency in producing the respective grain crop in different provinces. It is noted that the levels of the ranking have some connections with the proportion of the sown areas of the respective grain crops in provinces. The higher ranking is generally concentrated in the major producing provinces for the respective grain crops. For example, the

Table 9.1 Provincial Relative Production Efficiency in Wheat, Rice and Corn Production*

Province	Wheat	Rice	Corn
Beijing	59.15(1) [38.5]	147.08(3) [7.3]	134.29(1) [45.7]
Tianjin	59.26(1) [30.8]	152.78(3) [10.4]	135.64(1) [33.7]
Hebei	57.97(2) [36.5]		129.54(1) [29.5]
Shanxi	57.63(2) [30.9]		126.09(2) [18.6]
Neimenggu	49.01(3) [28.0]		121.51(2) [19.1]
Liaoning		191.52(1) [17.7]	144.32(1) [43.0]
Jilin		177.68(2) [11.4]	150.51(1) [59.6]
Heilongjiang	44.43(3) [21.8]	152.02(3) [8.5]	121.88(2) [27.4]
Shanghai	67.29(1) [17.3]	195.39(1) [61.2]	
Jiangsu	64.85(1) [36.4]	186.23(1) [37.8]	125.09(2) [7.5]
Zhejiang		172.60(2) [73.4]	
Anhui	55.81(2) [33.0]	155.87(3) [36.5]	112.51(3) [5.6]
Fujian		156.49(3) [74.1]	
Jiangxi		150.36(3) [89.3]	
Shandong	61.99(1) [50.3]		122.36(2) [29.4]
Henan	60.70(1) [51.4]	178.57(2) [4.6]	122.12(2) [21.9]
Hubei	50.96(3) [26.0]	163.37(2) [46.7]	106.06(3) [7.5]
Hunan		180.37(1) [81.8]	
Guangdong		135.50(3) [73.2]	
Guangxi		143.74(3) [69.9]	
Sichuan	62.30(1) [22.2]	213.79(1) [32.1]	97.61(3) [17.4]
Guizhou	46.99(3) [15.4]	180.55(1) [29.8]	84.69(3) [24.3]
Yunnan	54.16(2) [15.1]	180.37(1) [29.1]	89.66(3) [27.9]
Shaanxi	57.00(2) [41.3]		114.89(3) [24.1]
Gansu	56.60(2) [50.1]		114.21(3) [10.3]
Qinghai	55.09(2) [53.2]		
Ningxia	53.84(2) [42.6]	203.36(1) [7.9]	
Xinjiang	53.20(2) [64.6]		132.03(1) [24.0]

* The ranking of the intra-provincial levels is based on following intervals:
Wheat: >59 =(1); 51-59= (2); <51 = (3).
Rice: >180 = (1); 160 - 180 = (2); <160 = (3).
Corn: >130 = (1); 115 - 130 = (2); <115 = (3)

ranking of wheat is relatively high in Beijing, Tianjin, Hebei, Shanxi, Jiangsu, Shandong, Henan, Sichuan, Shaanxi and Gansu, where wheat sown areas account for a large proportion of the provincial total grain sown areas. A similar situation can be observed in corn production. In Beijing, Tianjin, Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, Shandong, Henan and Xinjiang, where corn production is concentrated, the ranking of corn is relatively high. The coherence between the proportion of the sown areas of the respective grain crops and the levels of production efficiency indicates a positive relationship between specialisation in grain production and production efficiency.

It is noted, however, that the major rice producing provinces do not always have a high value of d_i and, accordingly, a high ranking of production efficiency. For example, in Anhui, Fujian, Jiangxi, Guangdong and Guangxi, the value of d_i is low, despite the fact that they are the major rice producing provinces and sown areas of rice dominate grain production in these provinces. Conversely, in some non-major rice producing provinces in northern China, including Liaoning, Jilin and Ningxia, the ranking is relatively high. This feature, however, does not necessarily mean a production inefficiency in the major rice producing provinces. In Chapter 5, it has been argued that northern rice is Japonica rice, which is only produced in limited areas where natural conditions meet the special requirements of the growth of this kind of rice. The rest of the sown area is dominated by other crops, including wheat and corn. In southern provinces, Indica rice is the predominant grain crop. Wheat and corn production are constrained by natural conditions. The alternatives for different kinds of grain crops, therefore, are limited.[4] This result underlines the need to bear in mind the two different varieties of rice when making comparisons of performance of rice production.

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[4] In addition, the high genetic yield of rice and the ever-increasing demand for food grain in China have given rice a priority in the areas where rice production is suitable. This may further reinforce the necessity for rice production.

The intra-provincial production efficiency cannot be directly observed from the value of d_i. The judgement is, therefore, based on the relative ranking of grain crops with reference to national production. For example, if a province produces different kinds of grain crops and the relative ranking of these crops is different with reference to national production for the respective grain crops, then for this province, producing crops which have a higher ranking is considered to be more efficient than producing the crops which have a lower ranking.

Table 9.1 shows that in most multi-crop producing provinces, the ranking of different grain crops differs, indicating the variations in the relative levels of efficiency in producing different grain crops. For example, in Sichuan province, the ranking of wheat, rice and corn is 1, 1 and 3, respectively. This indicates that wheat and rice production in this province is relatively efficient compared with corn production. The variations in relative efficiency for different grain crops can also be observed in many other multi-crop provinces, such as Beijing, Tianjin, Shanxi, Neimenggu, Jilin, Heilongjiang, Jiangsu, Anhui, Shandong, Henan, Hubei, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia and Xinjiang. For most of these provinces, the higher ranking is possessed by the major grain crops in the provinces. This result indicates that a positive relationship between production efficiency and production specialisation also exists within individual provinces.

The variations in efficiency among provinces in producing the same grain crop and within provinces in producing different grain crops have important implications for the structural adjustment of grain production from the viewpoint of resource utilisation. For a respective grain crop, production should be concentrated in the provinces where the level of efficiency is high. For an individual province, the efficiency may be achieved by specialising in producing the crop for which the province has a relatively high efficiency. The general consistency of provincial relative efficiency and the specialisation of grain production shown in Table 9.1 indicates that the spatial distribution of China's grain production is relatively efficient in terms of national resource utilisation.

9.4 The Role of Provincial Governments in Grain Production

Progressive relaxation of central controls has been one of the marked features of the reforms of the Chinese rural economy. Generally speaking, the reforms have weakened the central planning system and increased the role of provincial governments in grain production management. The relaxation and decentralisation has meant that provincial governments have gained increased freedom to manage local grain production. The reforms have also provided incentives for provincial governments to care more about their own economic benefits. This concern, however, sometimes creates conflicts between provincial governments' grain production strategies, central government goals and the efficient use of provincial and national resources.

Compared with other activities in rural areas, grain production has received the least freedom. The central government's administrative intervention has maintained a strong influence on provincial grain production (Sicular, 1992). The existence of the grain quota means grain is still a semi-commercialised good, and the low purchase price still causes a loss in delivering quota grain in comparison to selling in the free market. From this point of view, for both farmers and provincial governments, the reformed grain production management system is only a partially decentralised system. Under this system, provincial governments are not entirely free to make their own production plans and to handle grain marketing. This, as shown below, has reduced incentives for provincial governments in grain production, which could lower the efficiency of resource utilisation.

In the partially decentralised grain management system, provincial governments have two roles. One is as the representative of the central government and the other is as the organiser of provincial production. Because of these two roles, on the one hand, provincial governments have to obey the grain production plan of the central government; and on the other, they also need to look after their own interests. These two roles have different implications for the economic benefits and losses of grain surplus provinces and grain deficit provinces.

The administrative intervention by the central government requires grain surplus provinces to supply large amounts of planned grain to the grain deficit provinces at the planned price, which is usually lower than the market price. This means that the grain surplus provinces have to forego the income that might have been obtained from higher market prices. Provinces which receive a large allocation of planned grain at low prices benefit from paying cheap prices for grain from the surplus provinces.

In a situation when grain is in over-supply, the grain surplus provinces often have difficulty in selling grain outside the central plan, as the grain deficit provinces refuse to buy more.[5] This causes a heavy financial burden for the grain surplus provinces to purchase and to store the surplus grain that farmers want to sell. The lack of grain storage capacity exacerbates the problem. It is reported that in Hunan province, various grain subsidies amounted to 1800 million yuan in 1990. All the grain stores were full and

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[5] This situation happened in 1984 and 1990-1992.

there were more than 1.5 million tonnes of grain stored outside (Yin Yue, 1992, p.33).[6]

It is clear that no matter whether grain is in shortage or is in over-supply, the grain surplus provinces are the losers and the grain deficit provinces are the gainers in the grain trade controlled through central administrative intervention. The low state grain price and the heavy financial burden, on the one hand encourages the grain surplus provinces to reduce the transfer of grain to the deficit provinces at the planned price; and on the other hand forces them to reduce the sown areas of the crops which are in surplus. For example, in Hunan and Jiangsu provinces, the rice sown area has decreased in recent years. In Shandong and Henan, the decrease occurred in the wheat sown area, and in Jilin and Heilongjiang, the sown area of corn decreased (SSB, *ZTN*, 1991-1993). Noting that large surplus provinces for respective grain crops are usually the major producing provinces, where the level of production efficiency is high, the reduction of the sown areas in the above major producing provinces will tend to lower efficiency in terms of national resource utilisation. Conversely, grain deficit provinces may have to increase the sown areas of the crops that they have no advantage in producing, resulting in a waste of provincial resources.

The conflict between the grain surplus provinces and the deficit provinces over the gains and losses in grain production is partly the consequence of central planning control over grain production and marketing. As grain cannot be traded freely in markets and the state purchase price is low, producing grain is less profitable compared with most other

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[6] There are many reports on the financial difficulties in the major grain producing provinces, such as Jilin, Jiangxi, Hunan, Sichuan. For details of these reports, see Yin Yue, 1992; Li Qingzeng, A. Watson and C. Findlay, 1991; Deng Yiming, Chen Jinsong and Yuan Yongkang, 1991.

activities. Provincial governments are generally reluctant to produce more grain. It is clear that this conflict can only be solved or eased by entirely removing central control over grain production, pricing and marketing. By doing so, the efficiency of resource utilisation in national grain production can be enhanced as a result of the specialisation of grain production in the provinces where resources can be used most efficiently.

9.5 Conclusions and Implications

This chapter has investigated the relationship between the spatial distribution of grain yield and the level of provincial production efficiency. It has also examined provincial relative efficiency in both inter-provincial and intra-provincial dimensions. The impact of the partial decentralisation of the grain production management system on the utilisation of national resources and the role of provincial governments in grain production have also been analysed.

It was found that there is a close relationship between the level of grain yield and the level of production efficiency. This result indicates that the variations in provincial yield are partly induced by the variations in natural conditions, the level of technology and the efficiency of production management. Production in the high yield provinces is more efficient in terms of resource utilisation, and the yields in a province are partly the result of poor production efficiency. Because of the effect of natural conditions, the variations in provincial production efficiency are partly inevitable. For individual provinces, available resources can be used more efficiently in producing grain crops for which the province has relatively suitable natural conditions.

In examining inter-provincial and intra-provincial relative efficiency, it was found that most of the major producing provinces for the respective grain crops have a relatively high level of production efficiency in comparison with the non-major producing provinces. Accordingly, in the provinces where more than one kind of grain crop is produced, the predominant grain crop often has a higher level of production efficiency than other grain crops. This feature implies that provincial specialisation in grain production is more efficient in terms of resource utilisation.

The role of provincial governments in grain production is shaped by their dual functions in the partially decentralised production management system. As a local representative of the central government, the interest of provincial government is consistent with the central planners. However, as an organiser of local production, the behaviour of provincial governments is also driven by their own interests. These two functions often mean provincial governments are unable to manage grain production by pursuing the path of the most efficient use of available resources. The partial decentralisation of grain production and the grain marketing system tends to decrease the level of specialisation in grain production. This can lower the efficiency of resource utilisation. It is therefore argued that removing the central government control over grain production, pricing and marketing is necessary for provincial governments to manage grain production more efficiently.

Finally, it needs to be pointed out that the analysis of grain production efficiency in this chapter is based only on resource utilisation within the grain sector. In reality, what farmers should produce and how provincial governments make their plans is not only determined by the relative efficiency within grain production, but also influenced by many other factors, such as relative efficiency in comparison with other crops and other sectors, the demand situation, transport costs, the consideration of food and income security, the limitation on growing season and so forth. Further discussion of these issues, however, lies beyond the scope of this study.

Chapter 10

Conclusions and Future Prospects

10.1 Introduction

Since the rural economic reforms began in 1978, China's grain output has experienced a remarkable growth. The result has been an improvement of food consumption. Food supply has changed from bare subsistence in the late 1970s to being reasonably sufficient by the mid 1980s, and this has continued into the 1990s.

Even though the growth has been dramatic, its course has been uneven. Great variations exist among provinces as well as among grain crops. During the early years of the reforms, rapid growth of grain output was a nationwide trend. After 1985, however, the growth was much less impressive. The overall growth slowed down. In some provinces, there were setbacks, reflecting the different effects of reform policies and the level of development of the rural economy on provincial grain production. In addition, because of diversities in natural conditions and variations in grain crops in different parts of China, the trends of growth in provincial grain production have been further complicated.

This study has examined the sources of output growth of grain production between 1978 and 1990. It focused on analysing changes in the total factor productivity of grain production and the contribution of these changes to the growth. Provincial disparities in the growth patterns of yield and their relationship to changes in total factor productivity were a particular concern. This study has also investigated the factors responsible for the changes in total factor productivity and the variations among different grain crops. Finally, it has examined the relative efficiency of provincial grain production and the role of provincial governments in utilising provincial resources.

This concluding chapter first reviews the major findings of this study and then extends these findings to a brief and general discussion of some policy implications, in particular, the effects of the latest developments in marketing and pricing trends on total factor productivity of provincial grain production in the 1990s.

10.2 The Summary of Conclusions and Major Findings

This study began in **Chapter 2** with a discussion of the notion of productivity in economic theory. This was followed by a review of the literature on Chinese agricultural productivity and grain productivity in the last 10 or so years.

The review found that there is a lack of common agreement among existing studies of Chinese agricultural productivity. Although all results of these studies have shown an increase in total factor productivity during the early 1980s, the measurements have varied significantly. Such variations are partly attributable to the lack of reliable data, in particular the data for labour inputs. Due in part to the data constraints, studies of productivity of grain production have not been common. In the few available studies, grain production is considered as a whole and/or examined at the national level.

Regional and disaggregated studies are rare. Yet China is a large country with great diversities in natural conditions and in the levels of socio-economic development. Grain production varies in different areas in terms of crops produced and yields achieved. It is, therefore, argued that the regional and disaggregated approach in studying grain productivity is both significant and necessary for understanding the mechanisms of the development of grain production and the disparities among provinces.

In China, studies of regional agricultural production often face a problem of regional definition. In **Chapter 3**, several commonly used definitions of regions in previous studies of Chinese agricultural production were reviewed and the characteristics of the each definition were discussed. It was found that although homogeneity has been most often used as a basic criterion in regional divisions, the homogeneous features in these definitions are often weak within the region, while heterogeneous features are not strong across regions.

It is argued that disparities among provinces are often significant and have been reinforced since the reforms began. The decentralisation meant that provincial governments came to play an increasingly important role in managing provincial grain production. This situation makes it more difficult to find common features among provinces, even when they are adjacent or close to each other. This is particularly the case for the provinces in the southeast and central areas of China, where grain production is most important with respect to the national overall production. This also explains why some provinces in these areas have often been integrated into different regions in different studies. The inconsistent definitions make the regional analysis less meaningful in terms of understanding regional characteristics and disparities in grain production.

After judging the merits and the demerits of different definitions in regional studies, it was argued that using the provincial boundary as the basic unit in the regional studies is more appropriate as it can best reflect the homogeneity within regions and the heterogeneity between the regions. In addition, Chinese official data are generally based on the provincial boundaries. Using provinces as regions provides insights into the effect of administrative intervention by both the central and provincial governments on grain production.

Chapter 4 examined grain production development between 1978 and 1990. It was found that since the reforms began, China's overall grain production has experienced significant changes in sown area, yield and output. These changes have made grain production in the reform era quite distinct from the preceding 1952-1978 period. One of the most dramatic characteristics during the reform period was the remarkable increase in grain output at a time when the sown areas decreased, indicating a great increase in grain yield or land productivity. Another finding in Chapter 4 was the uneven development of grain production during the reform period. This unevenness can be seen in both a time dimension and a regional dimension. The remarkable growth occurred mainly between 1978 and 1984, while after 1985, the progress was much slower. The uneven development across provinces increased the provincial diversities in grain production. Most of the increased grain output after 1978 came from large grain producing provinces, whereas the contributions of other provinces were relatively less significant. This required the study to place great emphasis on grain production in the major producing provinces.

As increasing yields were the major source of the increase in grain output during the period studied, **Chapter 5** investigated the growth patterns of yields between 1978 and 1990. It was found that the differences between the types of grain crops were responsible, to a large extent, for the disparities among provincial aggregate grain yields. Taking into consideration that the spatial distributions of grain crops are dominated primarily by natural conditions, it suggested that caution is required in comparing regional and/or provincial grain production. This finding underlined that the thesis as a whole needed to make an analysis based on respective grain crops. As wheat, rice and corn are the most important grain crops in China and they account for an overwhelming proportion of national grain production, the analysis of provincial grain production focused on these three grain crops.

In examining the growth patterns of grain yields, it was found that in many major producing provinces where the rural economy was developed, a dramatic increase occurred during the first sub-period and this was followed by stagnation during the second sub-period. Conversely, in most minor producing provinces where the rural economy was less developed, during the first sub-period, the yields increased relatively slowly but continued to increase in the second sub-period. This result indicates that different developmental levels in the rural economy can affect farmers' grain production responses to government policies.

The analysis of changes in total factor productivity for the respective grain crops and in different provinces was based on the production functions estimated in **Chapter 6**. Taking into account the effects of provincial disparities in natural environment and socio-economic development on the level of total factor productivity, the estimations of production function used a fixed effects model. This approach avoided using dummy variables in the model. More significantly, the values of the intercept terms provided the criteria for examining provincial grain production efficiency in terms of resource utilisation.

The estimations of production functions show that the output elasticity with respect to a particular input is different for wheat, rice and corn. This result demonstrates the necessity to estimate the production function for each grain crop separately in comparative regional studies of Chinese grain production.

Among various inputs, it was found that the output elasticity of land input was large for all the three grain crops, underlining the importance of the land input in grain output. Stabilising grain sown areas therefore is crucial to ensure a certain level of output. It was also found that the marginal returns of different grain crops to land input are different, with a large figure for rice and corn, and a small figure for wheat.

The estimation of production functions shows that output elasticity with respect to labour input is statistically insignificant for wheat, rice and corn. This corresponds to the existence of surplus labour in grain production. The output elasticity of labour input is difficult to estimate, as there were not enough variations of output that can be attributed to changes in labour input. This situation simply means that in Chinese grain production, labour input has become a non-binding factor. It also implies that increasing marginal labour input beyond the present stage may have little effect on marginal output. The further increase in output is determined by inputs of land, chemical fertiliser and other capital.

The output elasticity of chemical fertiliser and other capital inputs were positive and large in the estimations, suggesting the important role of these two inputs in increasing grain output given the limit on arable land. It was, however, found that the output elasticities of these two inputs varied among different grain crops. Given the 1990 price level, increasing chemical fertiliser input in corn production was more efficient than in rice production in terms of marginal returns of output and profit. For rice production, the small marginal output of chemical fertiliser input meant that further increase in this input might not be able to bring a large increase in rice output with the given amount of sown area.

Weather conditions are included in the estimation model as an explanatory variable. The significant and negative parameter indicates that grain output was inversely related to the areas affected by natural disasters. This result explained partly the uneven growth of grain output during the period studied. In the early 1980s, the rapid growth of output benefited from the good weather conditions and the poor harvests between 1985 and 1988 were, in turn, partly the result of the bad weather.

In **Chapter 7**, the estimated elasticities of various inputs were used as weights to compute the total factor productivity index of wheat, rice and corn between 1978 and 1990. It was found that the changes in total factor productivity were uneven during the period studied, and this corresponded to the changes in yield and output. The major increase occurred in the early years of the reforms. In the later years, total factor productivity only experienced minor changes. This result, suggests that the effects of the reforms on total factor productivity were most significant during the early years of the reforms.

The examination of the sources of yield growth reveals that the increase in total factor productivity was an important source of the growth. The result supports the view that the reforms have had positive effects on grain production efficiency. The comparison among the three grain crops, however, shows that the contributions of the total factor productivity to the yield growth were different, with a larger figure for corn and a smaller figure for rice. This result suggests that corn production performed more efficiently during the period studied.

The contribution of chemical fertiliser and other capital inputs to the yield growth was relatively small for all the three grain crops during the first sub-period and became significant in the second sub-period. This result indicates that farmers' grain production has tended to become more reliant on markets in purchasing producer goods. This trend underlines that the marketing and pricing situation has become increasingly important for farmers' production decisions. The inconsistent pace of changes in total factor productivity and output during the second sub-period can be attributed to the effect of the inconsistency of marketing policies.

The improvement in total factor productivity during the early years of the reforms, however, stemmed from the more efficient use of the available resources and technology, accumulated during the People's Commune period and released by the reforms in production organisation and the income distribution systems. Although the stagnation in the later years of the reforms was almost inevitable as the result of the depletion of the previous accumulation, the retreat of the state government from the role of key investor in agriculture and the failure to mobilise local investment to take up the role were also responsible for the stagnation. It is argued that with production moving closer to the potential of available technology, the further improvement in total factor productivity has to rely on new technology. Government policies in this respect were unsuccessful, and were a shortcoming of the reforms in the 1980s.

Having estimated changes in total factor productivity and their contributions to yield growth, an analytical model was established in **Chapter 8** to investigate the effects of changes in grain prices and material costs, the development of rural enterprises, changes in farmers' incomes and household grain sown areas on the changes in total factor productivity of grain production. One of the important findings was that the effects of farmers' incomes and the development of rural enterprises on the changes in total factor productivity differed between the early years of the reforms and the later years. This result underlines the significance of looking at the two sub-periods in analysing the causes of the changes in total factor productivity.

The study revealed that the initial increases in total factor productivity were closely related to farmers' short-term eagerness to improve food consumption and the long-term goal to increase incomes. The motivations to improve food consumption and to increase incomes reinforced each other and brought about a significant improvement in the total factor productivity of grain production during the early years of the reforms. However, once the food problems were solved, the motivation to increase incomes gradually became the key force driving farmers' production behaviour. The relatively low income from grain production was contrary to farmers' motivation, and became one of the reasons for the stagnation of total factor productivity during the late 1980s.

The estimated result in the analytical model seems to support the view that small farm size placed a constraint on the improvement of total factor productivity, despite the fact that for wheat and corn, the coefficient of this variable was statistically insignificant in the regressions. It is also argued that, possibly because of the extremely small size of household farm land, a slight increase in farm size may not be able to generate a significant improvement of economies of scale.

Based on the values of provincial fixed effects, estimated by using production functions, **Chapter 9** examined relative efficiency of provincial grain production in terms of resource utilisation. The role of provincial government in managing local grain production was also discussed.

The examination showed a consistency between the level of grain yield and the level of provincial production efficiency. This result indicates that the variations in provincial yield are closely related to natural conditions, the levels of technology and production management. Grain production in the high yield provinces tends to be more efficient in terms of resource utilisation, and the low yield in other provinces is partly the result of poor production efficiency.

The relative production efficiency in individual provinces was examined in both the inter- and intra-provincial dimensions. It was found that for respective grain crops, most major producing provinces have a relatively high production efficiency in comparison with the non-major producing provinces. Accordingly, in the provinces where more than one kind of grain crop is produced, the predominant grain crop often has a higher level of production efficiency than the other grain crops. This feature suggests that provincial specialisation in grain production is more efficient in terms of resource utilisation.

The role of provincial governments in grain production was examined from the viewpoint of their dual functions in the partially-decentralised production and marketing system. As a local representative of the central government, the interest of provincial government is consistent with the central planners. However, the decentralisation of production management also entrusted provincial governments with the responsibility to look after their own interests. These two functions sometimes meant that individual provincial governments were unable to manage grain production by pursuing the path of the most efficient use of available resources. This dilemma can only be resolved by entirely removing the controls over grain production and marketing.

10.3 Implications and Prospects for Growth of Total Factor Productivity in the 1990s

Entering into the 1990s, marketing and pricing reforms have accelerated. The centrally planned system of grain production has been further weakened and the trend towards entirely open grain markets is becoming increasingly stronger. Although the overall impact of this trend on total factor productivity is not yet clear, some likely outcomes can be considered based on the analysis of this study.

1) As administrative intervention by the central government impedes the improvement of provincial production efficiency, the further relaxation of the central control over grain production in the 1990s is likely to be conducive to encouraging provincial governments and individual farmers to adjust grain production in ways that available resources can be used more efficiently. It is predicted that, with the increasing relaxation of grain marketing and pricing controls, provincial production efficiency might be improved to a certain

extent, and the spatial distribution of overall national grain production will tend to become more specialised in the areas where resources can be used most efficiently.

2) Although the reforms in the last decade have been remarkable in creating incentives for farmers and provinces to improve production efficiency in grain production, the lack of agricultural investment in grain production has also partly been the result of the reforms, and has adversely affected the development of new technology and the construction of agricultural infrastructure. At the same time, new networks for promoting technologies in rural areas have not been developed to replace the commune system and to interact satisfactorily with the household-based production management system. Therefore, one of the important tasks faced by the government in the 1990s is to increase agricultural investment, to strengthen and to facilitate agricultural research, and to foster extension services. However, this task may conflict with the further relaxation of grain production marketing and pricing systems. Past experience shows that the reduction of central administrative intervention in grain production and the increasing role of provincial governments were accompanied by a reduction in agricultural investment, which has been detrimental to further development of new technology. Whether or not market forces can replace the role of the government in developing new technologies and in infrastructure construction is still an open question.

All in all, if the new policies cannot promote an improvement in technology, increasing grain output will have to rely primarily upon more inputs on the fixed amounts of land. This, in turn, will further worsen the relative prices between grain and other products due to the diminishing marginal returns to the inputs. Eventually, the overall output may decrease as a result of an out-flow of resources to other more profitable sectors. If the Chinese government is not comfortable with reliance on the international market to meet domestic grain demand, the relaxation will not be able to be maintained, because whenever the grain supply is in shortage, the government will tend to re-strengthen its administrative intervention. The policy swings between relaxation and consolidation of central control over grain production and marketing during the past years of the reforms have provided empirical evidence for this prediction.

3) The negative effect of the development of rural enterprises on the total factor productivity of wheat and rice in the late 1980s was mainly the result of the low relative profits and low net incomes in the grain sector. Much empirical evidence cited in this study suggests that this was caused, to a large extent, by the extremely small area of household farm and, consequently, by the low labour productivity. Increasing household farm size can allow household family labourers to be used more efficiently and labour productivity can thereby be increased. When farmers in grain production receive incomes equal to other sectors, their enthusiasm for grain production may be restored. Therefore, increasing household farm size has two related effects. One is to increase economies of scale so that total factor productivity can be improved. The other effect is to reduce the capital out-flow to non-grain sectors by increasing labour productivity in grain production so that labourers involved in grain production can receive the same wage as labourers in other sectors. This requires a threshold size of household farm land. Although the threshold size may not represent the best economies of scale in grain production, it may be the first stage in preventing a decrease in total factor productivity in grain production.

4) It was also found that specialisation in grain production can bring about a more efficient use of national resources. It is economically rational for the government to concentrate the limited investment on the areas where the production conditions, including natural, socio-economic and infrastructure conditions, for grain production are generally favourable. The construction of the commercial grain production bases starting from the mid 1980s may have reflected this intention. Such bases can only become fully effective, however, under the condition of the relaxation of controls over production and marketing, the realisation of economies of scale, the removal of grain trade barriers among provinces and the improvement of transport facilities for regional trade.

Whatever the impact of the reforms in 1990s, this study has demonstrated that the further increase in total factor productivity of grain production has to rely on the improvement of technology of inputs. From the point view of the government, two types of effort are indicated. One is to facilitate grain production through investment in agricultural research and in construction of agricultural infrastructure. The other is to introduce appropriate policies to encourage the market forces to work in favour of agricultural research and the distribution of new technology. However, introducing the market mechanism in agricultural research and distribution can only be realised when grain fully becomes a commodity and can be traded freely in markets. This requires the government to remove its control over grain production. The reforms in the 1990s seem to be moving towards this direction. Therefore, it is expected that the market mechanisms will become increasingly important in the further development of grain production.

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