IMPACTS OF
GREAT WESTERN DEVELOPMENT
ON AGRICULTURAL PRODUCTION
IN THE WEST OF CHINA

by

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Abstract

Great western development is a regional and preferential reform which began in the mid-1990s, and which intends to promote China's western economy. In this study, I statistically measure the effects of agricultural input growth, technological improvements and most importantly the improvement in institutional efficiency, which is attributed to great western development.

This measurement is pursued by first discussing general aspects of Chinese agriculture, including a brief history of China's agricultural economy and politics as well as agricultural policy changes after the reforms.

In order to estimate the effects of great western development on the Chinese agricultural production, I use the stochastic frontier production function. This approach is used widely in the field of economics in areas of measuring technical efficiency and policy effects in an industry with random shocks. I accompany this approach with several economic theories such as maximum likelihood estimation (MLE), measurement of technical inefficiency and estimation of technical change in the production function.

An important contribution of this thesis is empirical estimation of stochastic frontier production function for great western development and a hypothesis test using the Monte-Carlo method.

By maximum likelihood estimation with respect to the stochastic frontier production function, the measurement of the efficiency improvement is produced for the west and the east of China before and after great western development, respectively.

A conclusion, made after the empirical analysis, is that great western development has positive effects on agricultural production and productivity in the western China.

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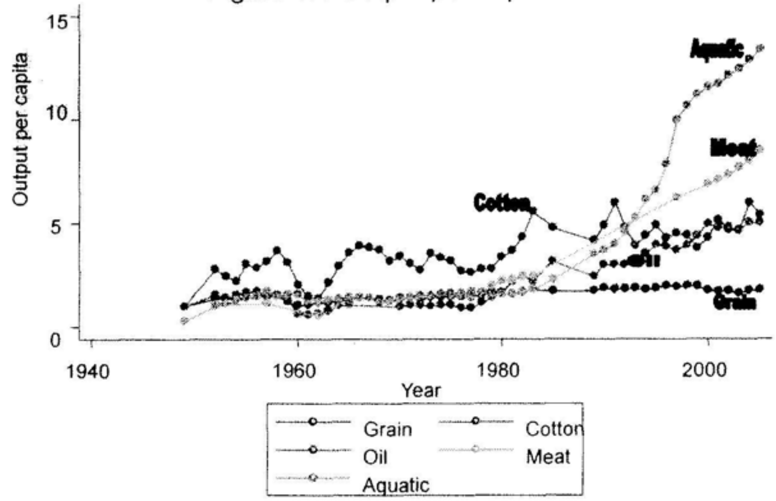
Chapter 1 Introduction

1.1 Background

Around one fifth of the world's population lives in China, and the Chinese population is still growing. However, China has only 7% of the world's cultivated land. Economists and policy-makers are concerned that the Chinese government cannot continue to provide enough food for its massive population. Despite many challenges, the Chinese government has done a reasonable job since the People's Republic of China was established in 1949. The output growth of agricultural goods per capita in China indicates that, except for the Great Leap Forward period (1958-1960), the growth in production of the major crops has generally kept up with the growth of population.

Figure 1.1 illustrates that the outputs of major agricultural products (grain, cotton, oil-bearing crops, meat and aquatic products) per capita has increased over the years. As figure 1.1 shows, all per capita outputs of major agricultural products have been increasing since 1949, especially after the 1980s. The per capita outputs of meat and aquatic products, luxury foods, have been increasing dramatically. This implies that China has been pursuing a higher level of food consumption since 1978. However, demand for crops per capita has not been significantly increasing during the past 30 years.

Figure 1.1 Output per capita



Data from China's Statistical Yearbook.

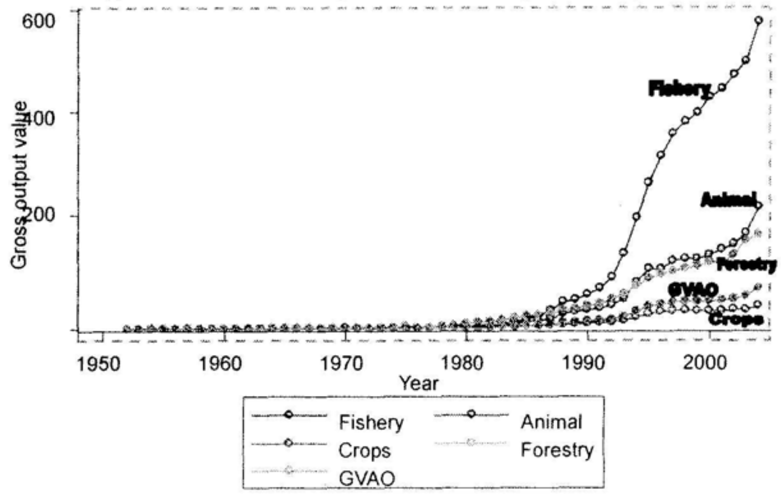
Notes: Grain: the indices of output of grain per capita (Grain=1 in 1949); Cotton: the indices of output of cotton per capita (Cotton=1 in 1949); Oil: the indices of output of oil-bearing crops per capita (Oil=1 in 1949); Meat: the indices of output of pork, beef and mutton per capita (Meat=1 in 1952); Aquatic: the indices of output of total aquatic products per capita (Aquatic=1 in 1952).

There have been three major institutional and policy reforms in the Chinese agricultural sector since the establishment of the People's Republic of China in 1949. The Chinese government executed land reform after 1949, and then, in late 1978, began the second reform, the so-called "Reform and Openness" policy. Figure 1.2 shows the change in the gross output value of the different agricultural products in China, clearly indicating that the gross output values of all kinds of agricultural industries have been increasing since the 1978 reform. The gross output values of fisheries, animal husbandry and forestry in particular have been soaring since 1978. Between 1949 and 1979, the growth rate of grain output (2.4%) was only 0.4% higher than the growth rate of the Chinese population (Lin, 1997). During the household responsibility system, which was executed in rural China from 1979-1984, the growth rate of the net value of agricultural products (7.73%) and grain production (4.85%), was much higher than the population growth rate (1.36%) (Lin, 1997).

It is important to note that the reform of 1978 caused uneven political and economic development in China. In particular, the western region remained poor relative to the eastern part of China. Although the 1978 Reform and Openness policy resulted in a long-term agricultural output growth rate that was one of the highest of all countries during the same period (Shenggen Fan, 1997), the eastern coastal provinces were better off than the central and western provinces under the new regimes. The growth rates of GDP and GVAO in the central and western regions were notably much lower than the ones in the eastern region (Shaoguang Wang & Angang Hu, 1999).

To address the problem of uneven regional development, the Chinese government has been implementing a third set of reforms, referred to as the "great western development". These reforms, which began in the mid-1990s, are being applied to the central and western regions of China.

Figure 1.2 Gross output value changes over years



Data from USDA

Notes: Fishery: the indices of gross output value of fisheries; Animal: the indices of gross output value of animal husbandry; Crops: the indices of gross output value of crops; Forestry: the indices of gross output value of forestry; GVAO: the indices of gross value of agricultural output. All the indices are based on the year, 1952.

The official western region, where the great western development is executed, comprises 12 underdeveloped western and central areas. Six of them are provinces (Gansu, Guizhou, Qinghai, Shaanxi, Sichuan, and Yunnan), five of them are autonomous regions (Guangxi, Inner Mongolia, Ningxia, Tibet, and Xinjiang), and the last one of them is a municipality (Chongqing), a provincial-level city, which is separated from Sichuan province for the purpose of western development. For consistency of data, Chongqing's agricultural inputs and output are combined into Sichuan's in the empirical model. The vast western region covers 71.4% of mainland China's territory (China Daily March 14, 2006). As indicated above, the region has very poor performance in terms of the contribution toward the Chinese GDP (gross domestic product). Therefore, development of the Chinese western region is an inevitable component of the next stage of China's development.

1.2 Thesis statement

The Great western development described above is the focus of this study. Many economists, using many different methods, have analyzed how Reform and Openness has influenced the Chinese agricultural economy. These studies strongly conclude that the Reform and Openness policy has had positive effects on agricultural production and productivity in China. However, there are no formal empirical studies which examine the impacts of the great western development reform on agricultural productivity. The Chinese government expects that this reform will have profound effects on agricultural production and productivity in the west in order to narrow uneven development between eastern and western regions caused by Reform and Openness. Therefore, it is important to determine statistically if the Chinese government's objectives are being met.

In this thesis, existing studies of Chinese agricultural productivity will be reviewed and techniques will be borrowed in order to measure statistically the agricultural productivity impacts of the great western development reform. Identifying the impacts of great western development on agricultural production and productivity growth is important in order for the government to take the next steps for on-going rural reform and effective input distribution. If the reforms associated with a conversion of the collective farming system into a household responsibility system (HRS) contributed the most to agricultural growth, then the government should strive to strengthen the HRS throughout the west of rural China. On the other hand, if more liberalized domestic and international markets have provided greater agricultural growth and more effective input distribution, then a market-oriented policy should be executed more thoroughly in the agricultural sector of the western region. Conversely, if the great western development is shown to have had a negative impact on the agricultural growth, collectivization and a plan-oriented market policy would be the logical course of the rural reform in order to offset the negative impacts and speed up agricultural growth in the west of China after mid-1990s. In my thesis, I will empirically examine **the extent that great western development has influenced agricultural production and productivity growth in the west of China and has caused technical efficiencies to improve faster in the west than in the east.**

Before addressing the objectives of this thesis, it is important to note that a major institutional change in China occurred in the 2001, when China joined the World Trade Organization (WTO). Although it might be argued that WTO accession will also affect Chinese agricultural productivity, this issue is not formally considered in the statistical analysis. One reason for this is that WTO-accession is expected to primarily influence prices of agricultural products. This is different from improving the capacity of the agricultural sector to transform a set of agricultural inputs into agricultural output.

1.3 Brief review of the literature

Many economists have measured the impact of the Chinese government's reform policies on the agriculture sector. Fan (1991) employed a frontier production function and introduced a new variable (technology) as a time trend in a standard production function model. Using a new methodology, Lin (1992) separately analyzed the different rural policies such as price reform, institutional reform and market and planning reform. Zhang and Carter (1997) created a new variable (weather index) within a production model and concluded that weather has had positive effects on production growth in the Chinese grain sector in the early 1980s.

There are only a small number of papers which address uneven economic development, which is the focus of this thesis. C. Cindy Fan (1995, 1997) described how Reform and Openness caused uneven economic development between the east and the west of China, the size of the economic gap, and what the Chinese government should do to narrow this gap. Lai (2002) describes the policies of China's great western development, how the reform has been carried out, and what results would be expected in the west of China.

Some more recent papers have examined the impact of WTO accession on the Chinese agricultural sector. Martin (2001) indicated how the reforms (including both Reform and Openness and WTO accession) have affected both domestic and international trade policies and as well as the trade environment in the Chinese agricultural sector. Huang and Rozelle (2002) concentrated on how the Chinese government and the household would respond to the challenges, and tested the performance of the Chinese agricultural market before the WTO accession.

1.4 Specific Research Objectives and Thesis Structure

As indicated above (see Table 1.1), many economists have analyzed the impact of the reform of 1978 on production and productivity growth using a variety of different methodologies. However, a review of the literature on Chinese agricultural productivity reveals a lack of formal analysis on the issue of how the impacts of great western development have improved agricultural production and productivity growth in the western regions of China relative to China's eastern regions. The specific objective of this thesis is to develop an econometric production function model, which incorporates the major inputs and the major reform variables, in order to assess the issue of uneven regional development within China's agricultural sector. In particular, the model will be used to explain empirically the influences of great western development on agricultural production and productivity growth in the west of China. The explanation will be in terms of technical efficiencies, and will compare the changes in technical efficiencies between the west and the east of China within the same time period. To capture regional changes in economic efficiency that have resulted from the great western development reform, a time invariant frontier production function model will be utilized.

The rest of this thesis is structured as follows. Firstly, the development of the

Chinese agricultural economy with some political reforms will be thoroughly discussed in chapter 2. In chapter 3, various existing theories and models, which are utilized within this study, are thoroughly reviewed and explained, and the basic model which is used for this thesis is presented. Following this, the data used in this thesis will be presented and discussed in chapter 4. The formal testing of the hypothesis and the results of the statistical analysis are presented in chapter 5. Chapter 6 of the thesis contains the conclusion.

Chapter 2 Development of the Chinese agricultural economy

There are three sections in this chapter. Ten economic and political periods in Chinese agricultural sector are presented respectively in the first section, which shows a brief history of China's agricultural economy and policies over time. In order to show the necessity of great western development, land reform, reform and openness and great western development, the three institutional and policy reform after 1949 are explained in the second section. This chapter is ended with a summary, the third section.

2.1 Brief history of China's agricultural economy and politics

The whole process of modern Chinese economic and political development can be divided into ten periods as follows. This division is based on the description provided by Fan (1997).

1. Three-year recovery and establishment period (1949-1952)

Before the establishment of the People's Republic of China in 1949, China had fought for eight years against the Japanese, encompassing World War II, and had also suffered greatly during the four-year Civil War. The fundamental institutions of the country were destroyed during these twelve years of bitter strife. The country needed a fresh start. The new communist government was formed in this period.

Right after the founding of the country under the communist party in 1949, the cultivated land, half of which was owned by landlords, was confiscated without compensation and assigned to the sitting tenants. The process of the land reform lasted until 1952. In the beginning of 1952, farmers could freely join or leave the new cooperative farms, formed by farmers voluntarily collecting their resources and cooperating together. In this period, the production of Chinese agriculture increased by 14.1% annually.

2. The first five-year plan period (1953-1957)

During this period, the government's strategy was aimed at the development of heavy industry. In keeping with the grand-scale outlook, relatively large agricultural collectives were promoted by the government in 1953. The progress of collectivization was successfully based on the voluntary collectives of the previous period initially. By 1956, collectives produced around 96% agricultural products. Only about 5% of all arable land was cultivated by households and they could sell the products from their private land on the free trade market. Chinese agricultural production and productivity grew at 4.5% and 1% per annum respectively.

3. The Great Leap Forward period (1958-1961)

The period is the most miserable period, in which 30 million people died of starving and malnutrition (Lin, 1997). The larger collectives, or communes, were promoted by the government, and in this period working on private plots was prohibited. The Chinese agricultural production and total factor productivity (TFP) annually declined by 14 percent and 15 percent respectively because of the failure of the large collective policy. Typically, one commune comprised 5000 households with 10,000 laborers and 10,000 acres of cultivated land (Fan, 1997).

4. Adjustment period (1962-1965)

The third period is the recovery period from the previous two years, in which the government adopted a more reasonable agricultural development approach. The communes were decomposed into smaller 'production units' with 20-30 households grouped together. The production units were the basic operating and accounting units under the communes. Unit leaders had rights to make the decisions on farm operations and adoption of new technologies. The land was still owned collectively and a laborers income still depended on his or her individual contribution measured by work points. The collective system was abolished in agricultural production by the late 1970s. Modern inputs, such as irrigation and the use of chemical fertilizers, had increased gradually after 1961. Modern varieties of agricultural products were promoted and adopted as well. In this period, both agricultural production and TFP grew at 9.4 percent and 4.1 percent per annum respectively (Fan, 1997).

5. The Cultural Revolution period (1966-1976)

This period is another miserable period, in which agricultural production growth was very low (4.0%) and productivity growth remained unchanged due to low incentives for farmers, inefficient input relocation and policy failure (Fan, 1977). Finally, President Deng proposed the Reform and Openness in 1978. The Chinese government controlled both inputs and output markets as well as the agricultural production, so an individual's income did not have close relation with his or her production contribution (efforts, skills or time). Consequently, farmers had poor incentives to achieve higher levels of production. Although the use of modern inputs (irrigation and chemical fertilizers) increased, high-yielding varieties replaced traditional varieties, and agricultural production was greatly mechanized after 1965, agricultural performance remained poor. The Great Leap Forward and the Cultural Revolution were both political failures, and the latter was the most damaging period in Chinese history after 1949.

6. Recovery period (1977-1978)

After the death of Chairman Mao and the chaos of the Cultural Revolution in 1976 President Deng Xiaoping came into power. It took some time for the Chinese economy to recover from the previous ten years, in which the Chinese economy remained stagnant.

7. The first phase of reform (1979-1984)

Agricultural reforms started in the late 1978s. The government raised the procurement prices of agricultural products, and re-opened rural markets so that peasants could sell the production from their private plots. The Household Responsibility System (HRS), which decentralized farming from the collective system to individuals' households, was proposed in 1981. By 1984, HRS had been adopted in more than 99 percent of production units and 97 percent rural area (Fan, 1997). Both technical efficiency and allocation efficiency of inputs and outputs increased in this period. This was due to both decentralization of the collective production system, and pricing and marketing reforms in the rural sector. As a result, both agricultural production and TFP grew annually at more than 9.4 percent and 5.1 percent respectively (Fan, 1997 & China's Statistical Yearbook).

8. The second phase of reforms (1985-1995)

The government reformed the procurement system "from a mandatory to a voluntary" system in 1985 (Fan, 1997). Contracts between farmers and the government determined the procurement quantities of some major agricultural products. There were no more procurement systems for secondary agricultural commodities. By 1985, the 113 agricultural commodities listed under the procurement system were reduced to 38 commodities and by 1991 to only 9 (Fan, 1997). Agricultural pricing and marketing systems were decentralized further and deeper, even in the grain market. The grain rationing system was removed after 40 years existence. The markets for vegetables, fruits and fishery products were opened in 1987. By 1993, farmers traded over 90 percent of all agricultural produces in the free markets at market-determined prices (Fan and Pardey, 1997). Therefore, the allocation efficiency of agricultural inputs and outputs was improved further. Agricultural production continuously increased at an annual growth rate of 6.1 percent, and the TFP increased at an annual growth rate of 4.0 percent annually (Huang & Rozelle, 2002a).

9. Continuous development, great western development and the pre-WTO-accession period (1996-2000)

Since the reforms begun in 1979, China's economy had soared rapidly. However, two-tier pricing system and self-sufficient policies gave rise to heavy burdens for the Chinese government. Market liberalization spread in the food market for almost twenty years, but there still were relatively non-transparent state trading arrangements in many agricultural goods markets. These reduced the growth rate of agricultural production to 3.4 percent per annum (Fan, 1997).

The regional gap of economic development widened considerably, for several reasons. In particular, large investments by the central government and foreign countries favor the eastern coastal provinces. In addition, preferential policies are oriented towards the eastern part of China. For example, the central and western inland regions mainly produced primary commodities and agricultural goods. The prices of these goods were substantially lower than the prices of finished and industrial products, which were produced in the eastern coastal provinces. The structure of 1994 production is displayed in the table 1a in the Appendix. The data shows that the most western provinces were more concentrated on producing agricultural products than the eastern provinces. Therefore, the interior provinces suffered "double losses", selling primary and agricultural goods at low prices to the eastern coastal provinces while purchasing finished and industrial products at high prices from those provinces.

Complaints about widening regional inequality, the outflows of resources from poor interior provinces to wealthy coastal provinces, and regional protectionism pushed the Chinese government towards narrowing the regional gap as one of primary targets in this period. Demurger et al. (2002) estimated that the impacts of geography and policy reforms on GDP growth rate in the various regions from 1996 to 1999 were 2.5% and 3.5% for the province-level metropolises (Beijing, Shanghai, Tianjin, and Chongqing), 0.6% and 2.3% for the northeastern provinces, 2.8% and 2.8% for the eastern provinces, 2.0% and 1.6% for the central provinces, 0% and 1.6% for the northwestern provinces, and 0.1% and 1.8% for the southwestern provinces. This indicates that policy reform had a greater effect than geography in the west regions in this period. Therefore, the great western development policy was clearly having some impact.

Huang and Rozelle (2002b) have tested the market integration of China's agricultural sector and have concluded that the Chinese agricultural market functioned well and the market was relatively integrated in the five years before WTO accession, and, further, that there was evidence of rising estimated integration in the market.

10. WTO Accession period and development both in the western region and the whole country in the 21st Century (2001-present)

Most economists considered WTO accession as an extension of the past reform because of the gradual decline in tariff and other forms of protection within the Chinese agricultural sector since 1978. Even though WTO accession would give rise to some negative impacts on some agricultural commodities, it is believed that the government will be able to reduce the negative impacts in several ways. These include devaluing the Chinese currency (to encourage export and discourage import), decreasing the implicit tax imposed on exportable goods (to encourage export), increasing the tax on imported commodities (to reduce the importers' profits and the quantity of import), increasing export subsidies (e.g., for maize and soybeans), rebating the value-added tax and reforming traditional trade policies, tariffs, quotas and licensing, state trading and non-tariff barriers (NTBs).

For some crops, such as maize and cotton, WTO accession may cause a decrease in prices and an increase in imports. For some agricultural commodities such as rice and horticulture products, however, China has a relatively large comparative advantage, so WTO accession could provide opportunities for China to benefit from export of the commodities. As well, if maize, the feed grain, is imported at a lower price, the cost of producing livestock is reduced, implying that domestic livestock would be more competitive in the world market. Under WTO accession rules, the Chinese government retains the power to protect some domestic goods, limiting the potential for damage to the agricultural sector. In addition, households could respond to an initial loss in many ways, for example by adopting more efficient technologies. For example, the Chinese agricultural production grew at 2.9%, 2.5%, 6.3% in 2002, 2003, 2004 respectively, which shows that WTO accession had a negative impact on the agricultural production initially, but also that the government and farmers adjusted in the following years effectively (NBS). In this period, the Chinese agricultural production increased by 4.8 per annum.

The following table briefly describes and concludes changes of the growth rate of production and TFP during the above periods respectively. It gives a simple intuition on the path of the effects of institutional and policy reforms on the agricultural production and productivity. There are steady growth rates in the agricultural production and productivity in the periods after 1978. And the growth, caused by WTO-accession, is just an extension of the growth due to previous reforms.

Table2.1 Growth rate of production and total factor productivity (TFP) within the different periods in the Chinese agricultural sector

Periods	Production growth rate	TFP growth rate
1949-1952	Grew at 14.1% annually	N/A
1953-1957	Grew at 4.5% annually	Grew at 1% annually
1958-1960	Declined by 14% annually	Declined by 15% annually
1961-1965	Grew at 9.4% annually	Grew at 4.1% annually
1966-1978	Grew at 4.0% annually	Unchanged
1979-1984	Grew at 9.4% annually	Grew at 5.1% annually
1985-1995	Grew at 6.1% annually	Grew at 4.0% annually
1996-2000	Grew at 3.4% annually	N/A
2001-2005	Grew at 4.8% annually	N/A

Data from Fan (1997), Huang & Rozelle (2002a), Wen (1993) and various issues of China's Statistical Yearbook.

2.2 Summary of Chinese agricultural institutional and policy reforms

In this section, major agricultural policies in the different periods are summarized, providing a clearer view of the effects of institutional reforms on agricultural policies and productivity.

2.2.1 Agricultural policies before 1978

Before the Reform and Openness policy of 1978, the Chinese government developed several major institutions, described as follows:

(1) The collective farming system: farmers worked in large production units, and their work was monitored and measured by supervisors with a work-point system.

Private trade was prohibited within this system, except for a limited amount of agricultural commodities produced on private land, which was only 5% of the cultivated land.

(2) The state-monopolized procurement and marketing system for grain, cotton, and other major farm products: farmers did not have rights to sell any agricultural commodities produced within collective production units. All commodities were traded under the collectives' authority. As well, the exchange of land between different collectives was outlawed.

(3) A grain self-sufficient policy: grain was required to be produced at a self-sufficiency level within each region, even if the weather and land were not suitable for planting grain. This policy created a significant misallocation of resource due to inefficient input and output decisions. The policy was part of a larger plan-based farming system, under which the government controls not only sown acreage for each crop but also the levels of outputs, inputs and so on.

(4) Central-planned and monopolized trade regimes: in the pre-reform period (before 1979), between 10 and 16 Foreign Trade Corporations (FTCs) dominated the Chinese foreign trade market (import and export). The planned level of exports financed the planned level of imports, which was determined by the differences between demand and supply for certain goods including agricultural products in the domestic market.

2.2.2 Agricultural policies resulting from Reform and Openness

After 1978, the Chinese government executed a series of fundamental reforms as follows:

(1) Institutional reforms: the collective system had been transformed into a household responsibility system (HRS), which resulted in decentralization of decision making within the farming system. Individual households had been given the rights over input distribution within their own farms, which was operated under contract. The farmers' incentives were improved due to the closer relationship between their incomes and labor effort. The HRS ensured that the land owned by collectives was redistributed to individual households with a maximum contract length of fifteen years, and those contracts could be extended for another thirty years in 1993, so farmers are able to use their land more freely.

(2) Price reform: under state-monopolized procurement and marketing system there existed two prices for certain agricultural products. One was the quota price, and the other was the above-quota price. The quota prices for grain and oil crops were raised from 30 percent to 50 percent and the above-quota price for cotton witnessed a 30 percent bonus (Lin 1992). The retail prices for pork, fish and eggs grew by one-third, but the retail prices for grain and edible-oil did not change. The mandatory quota procurement had been abolished and transformed to a voluntary contract procurement system, under which the contracts were negotiated between the

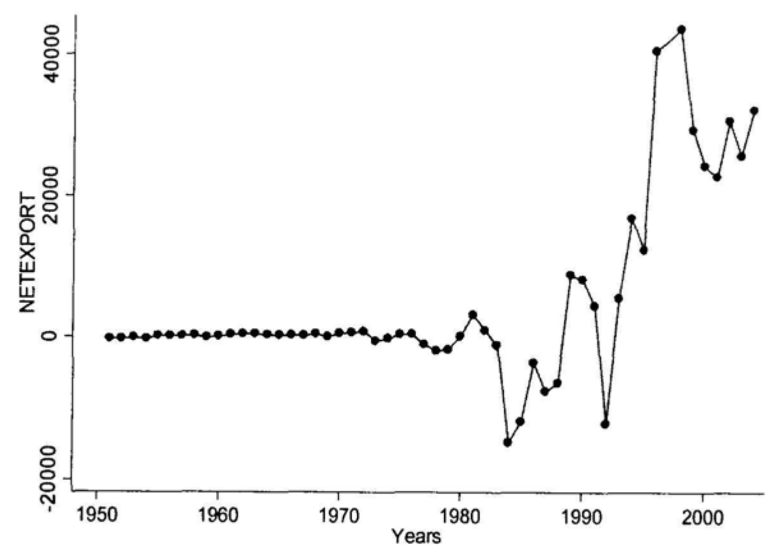
government and the farmers.

(3) Marketing and planning reform: Contrary to the self-sufficiency policy in the pre-reform period, after the 1978 reform the Chinese government encouraged grain imports, reduced procurement quotas of agricultural products, and then introduced procurement contracts between farmers and the government. The government eventually abolished the procurement quota system, which meant that farmers could sell their grain in the free market at the free market price. The restriction on grain self-sufficiency and trade within regions were also relaxed. In general, the Chinese government liberalized the agricultural market by providing farmers with the rights to sell their agricultural commodities in the free market. In effect, the Chinese government turned a central-plan based economy to a market-oriented economy.

(4) Trade regimes: after 1978 and before WTO-accession, the Chinese government reduced sharply the protection of domestic producers from foreign trade. The estimates of nominal protection rates (NPRs), provided by Huang, Rozelle (2002b), demonstrate that the decrease in protection of the Chinese foreign trade was sizable. Starting in 1978, the foreign trade regimes were gradually decentralized, and more than ten times as many foreign trade corporations were established. The prices of agricultural commodities were increasingly aligned with prices in the world market. The Chinese government also introduced the export tax rebate system and export subsidies in order to promote exports.

Figure 2.1 presents net exports in the Chinese agricultural sector. There is almost no international trade activity in China's agricultural sector before the 1978 reform. After the reform, international trade became active. In the beginning of the 1978 reform, the net exports are roughly negative, which means agricultural imports are greater than the exports. The net exports have been increasing since the early 1990s. The imports increase faster than exports after 1998. The period between 1998 and 2001 is the period of preparation for WTO-accession, so some international trade policies have been altered according to WTO requirements in that period, which potentially makes the Chinese international market more transparent and easier to enter.

Figure 2.1 Chinese agricultural net exports (million US dollars)



Data from USDA

Table 2.2 below summarizes the different agricultural institutional systems and policies before and after Reform and Openness, which have been discussed above. There were no large changes of agricultural policies between the 1978 reform period and the WTO-accession period. The market and associated policies become more transparent and free. For great western development, this is merely the continuity of Reform and Openness in the west of China, explained in the next subsection.

Table 2.2 Agricultural institutional systems and policies in pre- and post- reform

	Development strategy and agricultural policy	Institutional farming system	The grain policy reform	Marketing system	Price policy	Trade policy
1949-1978	Industry-oriented development strategy	Collective	Grain self-sufficient policy	Central plan-based & state-monopolized	Quota and above-quota prices	Monopolized
1979-Present	Market-oriented development strategy	Household responsibility system (HRS)	Contract-based & self-sufficient policy later	Free market	Price increase and finally free market price	Decentralized

2.2.3 Great western development policy--agricultural policies in the western region after mid-1990s

In 1992, President Deng realized that the uneven development would become a serious problem in the near future. A policy to narrow the gap in development between regions was proposed and approved in the 9th five-year plan at the Fifth Plenary Session of the 14th Party Congress, held in September, 1995. Following that, President Jiang emphasized the rural poverty problem in June 1996, and intended to improve the situation by a considerable amount by the end of 2000. Most poverty is located in the central and western regions. The key to solving the rural poverty problem is improving agricultural production in the vast western regions. Thus, the first stage of great western development, which influences western agricultural production the most, took place in mid-1990s.

President Jiang first used the phrase 'great western development', at the conference on the Reform and Development of State-Owned Enterprises in the Five Northwestern Provinces in Xi'an on July 17th, 1999, and also emphasized that reduction of the regional gap in development should be gradual, which is the lesson that should be learned from the Great Leap Forward (see section 2.1).

In order to resolve the problems of uneven development, the Chinese government developed improved reform and openness policies, which influence agricultural production in the western provinces, as demonstrated below:

(1) Institutional reforms (HRS): although the household responsibility system (HRS) was also applied to the western provinces after 1978 reform, it was not as thorough and complete as it was in the eastern provinces. The central government encouraged the eastern coastal region to get rich first, leaving the western region less supervised. The local government in the west did not wish to execute HRS in farming, and in some parts of the western region the farmers are too poor to apply HRS, because they

have to support each other by the collective system.

As described in section 2.2.1, under the collective system, farmers earn work-points based on their working time and ability, and they do not have the right to sell their products. Consequently, farmers do not gain direct profit from their agricultural activities because all profit belongs to the collectives. After the mid 1990s, the central government fixed its focus on the west of China. More land was redistributed to individual households. Farmers can decide the usage of their land, and they can sell their agricultural products in the free market under HRS, so they can earn direct profits from their work. This policy is expected to be the main cause of the increase in technical efficiency in the west, because more profit encourages farmers to work harder on their land.

(2) Price reform: the "double losses" for western provinces, which are caused by selling low-price primary and agricultural products and buying high-price finished and industrial products that are produced by eastern provinces, made the regional gap in development greater than ever. Therefore, increasing the prices of primary and agricultural products is an important component of reform. However, price reform does not influence technical efficiency directly. Higher prices induce more production but not necessarily higher productivity.

(3) Market openness: encouraging provincial, domestic and international trade is the main method of opening the market in the west of China.

(4) Investment: the Chinese government has increased investment in the control of soil erosion and desertification, and also irrigation projects in the western regions. Besides the Chinese government's own investment, the national government gives the western provinces favorable tax and other policies in order to attract domestic and foreign investment into the western regions.

(5) Agricultural production structure: western provinces have geographic advantages in forestry and animal husbandry, but are less favoured for that of cropping. Therefore, encouraging agricultural production, forestry and animal husbandry makes the western provinces develop faster. This policy also causes increases in technical efficiency due to shifting to more advantaged and more efficient agricultural production, but it does not cause increases in technical efficiency of specific individual agricultural production. It makes farmers choose more efficient products over less efficient ones.

2.3 Summary of this chapter

This chapter attempted to provide an overview of the Chinese agricultural economic and policy reforms. The years since the establishment of the People's Republic of China in 1949 are divided into 10 periods, according to the specific characteristics of agricultural economy and policy within each period. Each period's particular agricultural production, productivity and major policies have been highlighted. By comparison the production and productivity data among the periods, it can be concluded that the Chinese agricultural production generally increased except for the 1958-1960 period, and the WTO-accession is an extension of the progress of the 1978 reform.

In the second section of this chapter, the agricultural policies, in the pre- and post- 1978 reform periods and after the approval of great western development, were explained in detail. Through a comparison of the Chinese agricultural policies in those three periods, it can be concluded that agricultural policies in price, trade and market have been decentralized step by step, and great western development is a re-enforcement of the 1978 reform in the west of China. Because the 1978 reform did not deeply influence agricultural production in the west of China, the Chinese government executed more profound reform in the western regions, the 'great western development'.

Chapter 3 Theory and model development

In this chapter, various economic theories and models, which focus on measuring technical efficiency and the effects of institutional reforms, are reviewed and discussed. This review allows for the construction of a stochastic frontier production function model for use in this thesis.

3.1 Production with technical inefficiency

The concept of technical efficiency must be incorporated into a stochastic production function model in order to capture the effects of institutional reforms. The production function is said to be technically efficient when the function can maximize the output values from any combinations of input requirement sets. For instance, a worse input combination or input distribution caused by an unsuitable institutional framework can induce technical inefficiency (waste of some inputs). Therefore, an efficient production process, "in which a higher rate of output can be obtained only if there is a higher rate of input for at least one of the elements of production," is necessary to maximize the agricultural output (Asimakopulos, 1978).

Awh (1976) defines a production function as follows: "The production function shows the maximum quantity of output, q, that can be produced as a function of the quantities of inputs, labor and capital, used in the production processes".

Kumbhakar and Lovell (2000) define a production frontier as follows: "A production frontier is a function $f(x) = \max\{y : y \in P(x)\} = \max\{y : x \in L(y)\}$" where P(x) is the output sets, L(y) is the input sets with certain properties:

"P1: $f(0) = 0$;

P2: f is upper semi-continuous on R_+^N;

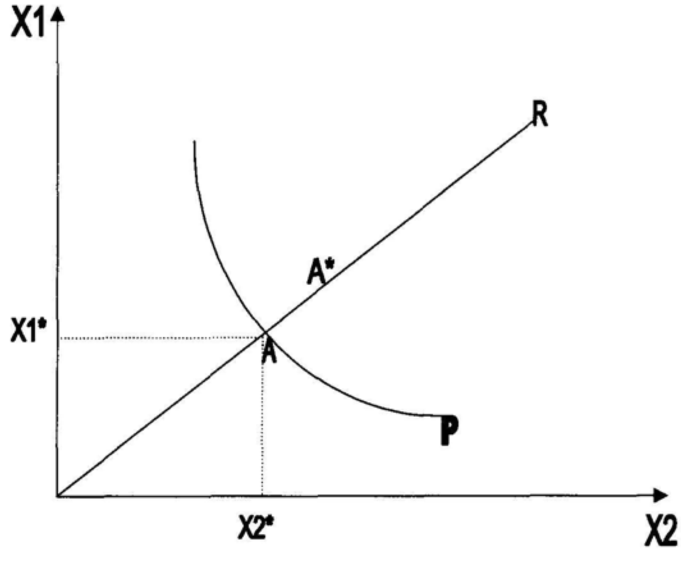
P3: $f(x) > 0 \Rightarrow f(\lambda x) \to +\infty$ as $\lambda \to +\infty$;

P4: $f(\lambda x) \geq f(x), \lambda \geq 1$ for $x \in R_+^N$ (weak monotonicity property)."

Note that property 2 means that the production function is continuous in the domain of positive real number not including 0.

In general, a production function provides a relationship between inputs and output, which typically varies over time due to technical and institutional changes. For example, before 1979 Chinese agricultural labor faced relatively poor incentives under the institution of collective production. Consequently, agricultural production is relatively inefficient as compared to the institution of HRS, in which case the incentives were improved because of the closer relationship between the efforts of a laborer and his or her income. The output-input relationship caused by institutional inefficiency is illustrated in figure 3.1 and figure 3.2, which were originally presented by Fan (1990). For simplicity, only two inputs are introduced in this set of graphs.

Figure 3.1 Production with the inefficiency and two inputs in one region (a country as a whole)



In the figure 3.1, P is an isoquant associated with the production function. Under the efficient situation, an input combination of X1* and X2* is needed to achieve output A. However, because of the inefficiency, the realized input combination is A*, which is more than A. Therefore, under the inefficient conditions, more inputs are required for the same level of output. Figure 3.1 presents production with technical inefficiency in one region.

China is the third largest country in the world. There are more than thirty provinces in the country. The production efficiencies within the different regions vary considerably even though the provinces are under the same institution of the Chinese communist party. This variation occurs because the same policies have different impacts on agricultural production within the different regions. Figure 3.2 illustrates production inefficiencies in two hypothetical regions.

Figure 3.2 Production with two inputs and inefficiencies in two regions

Figure 3.2 has been removed due to copy right restrictions. The information removed is originally presented on page 36 of Fan (1990). The figure is similar with figure 3.1, but there are two regions in this graph. The detail description is in the next paragraph.

In Fan (1990), PC1 and PC2 are production isoquants in region 1 and region 2. A and B are input combinations for a specific level of output in region 1 and region 2. As in figure 3.1, because of production inefficiency, the realized input combinations are A* and B* for the same amount of output. As indicated earlier, producing the same level of output needs more inputs in the inefficient situation.

3.2 Technical change over time in the production function

Technical change in Chinese production technology has been estimated by economists who use econometric analyses on time series data. A "time term" is incorporated into the production function in order to capture the technical change over time, which is demonstrated by a shift in the production function. Figures 3.3 and 3.4, which were originally presented by Chambers (1988), illustrate how technical change can be illustrated graphically.

Assume that inputs are held fixed over time, and the basic form of the production function remains the same. The production function can be represented as $y = f(x,t)$, which implies a stable relationship between output, input, and time (t) denotes a "time term". Holding inputs constant, a change in output implies technical change as time elapses. If the production function $y = f(x,t)$ is differentiable with respect to "time" (t), then $T(x,t) = \dfrac{\partial f(x,t)}{\partial t}$ measures the rate of technical change (the technical improvement per year).

Figure 3.3 Progressive technical change

Figure 3.3 has been removed due to copy right restrictions. The information removed is originally presented on page 206 of Chambers (1988). The detail description is in the next paragraph.

In figure 3.3, X1 and X2 are inputs for the one product. The present year and the previous year are denoted by t and t' respectively. V (y, t) and V (y, t') are input requirement sets in the present year and the previous year.

The figure 3.3 illustrates the progressive technical change, in which $t > t'$ and $V(y, t') \supseteq V(y, t)$. It indicates that in order to produce the same level of output y, the input bundles with the same weight of input combination shrinks. Conversely, if $t > t'$ and $V(y, t) \subseteq V(y, t')$, the input bundles are expanded so as to produce the same level of output y in the regressive technical change situation.

Figure 3.4 Locally progressive technical change

Figure 3.4 has been removed due to copy right restrictions. The information removed is originally presented on page 206 of Chambers (1988). The detail description is in the next paragraph.

Figure 3.4 illustrates a situation of locally progressive technical change, in which case $t > t'$ and $V(y, t)$ intersects $V(y, t')$. It demonstrates that in order to produce the same level of output y, the input bundles shrink with the different input combinations. In reality, locally progressive technical change is likely to be more common than the phenomenon in the illustrated figure 3.3. For example, some new technologies of high-yielding crop varieties allow farmers to save on one type of inputs but require more of another type of input, such as fertilizer and water in order to produce the same level of output y. In the locally regressive case, more particular inputs are required within the new technologies.

In a general functional form, the shift in figure 3.3 can be measured by using the parameter of the "time trend" (t) variable. The shift in figure 3.4 can be measured by using the parameter of the "time trend" variable as well as the interaction terms between inputs and time trend variables. The parameter of the "time trend" variable measures the shift induced by labor learning and other regular factors. The parameters of the interaction terms measure the shift induced by new technologies which require less of certain inputs in the locally progressive case. In principle, inputs and technical change (t) are assumed to be independent in figure 3.3 and dependent in figure 3.4.

For simplicity, the interaction terms between inputs and time trend variables are not involved in this study, but the introduction of them is necessary.

3.3 Frontier production function

3.3.1 Theory of frontier production function

When using an average production function, only the effects of technical changes and various inputs on production growth can be estimated. The effects of institutional changes on production growth are necessarily combined with the effects of technical improvement. Therefore, the effects of technical improvement are overestimated in the average production function. To eliminate this problem, a frontier production function can be utilized. The frontier production function can measure the effects of inputs, technical and institutional or inefficient changes on production growth. The frontier production function approach was studied by Farrell in 1957 initially and the approach has been used in a wide range of economic areas.

There are several alternative approaches associated with the frontier production function such as the programming frontier approach, the deterministic frontier approach and the stochastic frontier approach. Random shocks are only allowed in the stochastic frontier approach. Therefore, a stochastic frontier production function is employed in this study in order to capture the random shocks out of production inefficiency. A stochastic production function model allows for separating technical efficiency from random residuals outside producers' control. The random residuals include the residuals (u_i) from the inefficiency and the residuals (v_i) from some uncontrollable agricultural factors such as luck, weather, specification errors and omitted variables without correlation with included regressors. Figure 3.5, which was originally presented by Fan (1990 & 1991), illustrates how a frontier production function measures the effects of inefficiency over time.

Figure 3.5 Effects of input, technology and institutional reform on production growth

Figure 3.5 has been removed due to copy right restrictions. The information removed is originally presented in Fan (1997). The detail description is in the next paragraph.

X and Y represent production input and outputs respectively. Time 1 and time 2 are denoted by 1 and 2. Frontier 1 and frontier 2 are the production frontiers that producers faced at time 1 and time 2. The Ts are the potential outputs with perfect efficiency, and the Es indicate the inefficiency between realized and potential production with the different inputs in the certain time period. Z demonstrates the distance between the two potential outputs with the different inputs X1 and X2. Therefore, "the total production growth can be decomposed to three effects: input growth (Z), technological change (T2-T1), and efficiency improvement (E1-E2). Namely, Y2-Y1=Z + (T2-T1) + (E1-E2)."

3.3.2 Modeling efficiency with a frontier production function

The stochastic frontier production function is applied in this study in order to determine the effects of institutional reforms on production growth. This idea is from Fan (1991), who notes that "Technological change is defined as a shift of the frontier production function. Efficiency improvement is defined as the decrease in the distance between the firm's realized output and its potential output (or frontier)".

In the stochastic frontier production function, the error term (ε_i) is decomposed into two error terms (v_i and u_i). Therefore, $\varepsilon_i = v_i + u_i$, where v_i denotes the random residual, which is assumed to be normally and identically independently distributed, namely $v_i \sim N(0, \sigma_v^{\ 2})$. Similarly, u_i captures the effects of random shocks in inefficiency, which are assumed to be negative and one-sided normally and identically independently distributed, namely $u_i \sim N(-\mu, \sigma_u^{\ 2})$.

The general form of the stochastic frontier production function model is:

$$y_i = \beta' X_i + \varepsilon_i, \quad \text{and } \varepsilon_i = u_i + v_i, \qquad i = 1, \dots, N,$$

Where y_i = a vector of output (realized output);

X_i = a vector of inputs;

β = an unknown parameter vector to be estimated;

v_i = the symmetric disturbance with independent and identical distribution as $N(0, \sigma^2)$;

u_i = the technical inefficiency with one-sided negative independent distribution as $N(-\mu, \sigma^2)$.

v_i and u_i are distributed independently of the input variables in the model and $E(v_i u_i) = 0$.

In this case, $\beta' X_i + v_i$ represents potential output or the production frontier, which producers face. Non-positive values of u_i indicate that the realized output (y_i) has to lie on or below the frontier. In principle, the production technical efficiency variable (TE_i) is the ratio of the realized output and potential output, which has values between 0 and 1. Therefore,

$$TE_i = {y_i}\Big/{(\beta' X_i + v_i)}$$

3.3.3 Functional form of frontier production function

In this study, the Cobb-Douglas functional form is used to approximate the Chinese agricultural production function. The theory of the Cobb-Douglas production function is nicely described in Asimakopulos (1978) and Awh (1976). For exposition purposes, assume that only two inputs are required for production. Generally, the function takes the form,

$$Y = AX_1^{\alpha} X_2^{\beta} \qquad \text{(E 3.1)}$$

Where Y denotes output; X_1 and X_2 denote inputs; α and β are fractions; and A is a constant.

The Cobb-Douglas functional form has several useful features, in particular:

(1). Logarithm of the Cobb-Douglas function is linear.

$$\log y = \log A + \alpha \log X_1 + \beta \log X_2 \qquad \text{(E 3.2)}$$

It is simple to deal with empirically, For example, ordinary least squares (OLS) estimation can be employed to estimate A, α and β easily.

(2) α and β are the output elasticity coefficients for inputs X_1 and X_2. The definition of the output elasticity (ξ) is "the ratio of the relative change in output over a relative change in an input" (Awh, 1976).

The output elasticity of inputs X_1 is

$$\xi_{X_1} = \frac{\partial Y / Y}{\partial X_1 / X_1} = \frac{\partial Y}{\partial X_1} \bullet \frac{X_1}{Y} \qquad \text{(E 3.3)}$$

$$\frac{\partial Y}{\partial X_1} = A\alpha X_1^{\alpha-1} X_2^{\beta} \qquad \text{(E 3.4)}$$

Substitute (E 3.1) and (E 3.4) into (E 3.3):

$$\xi_{X_1} = A\alpha X_1^{\alpha-1} X_2^{\beta} \bullet \frac{X_1}{AX_1^{\alpha} X_2^{\beta}} = \alpha \qquad \text{(E 3.5)}$$

Apparently, this feature holds for the other inputs, X_2, in the functional form.

(3) α and β also demonstrate the relative distributive shares of inputs X_1 and X_2.

The relative distributive share of input X_1 is $\dfrac{\frac{\partial Y}{\partial X_1} \bullet X_1}{Y}$.

Substitute (E 3.1) and (E 3.4) in, and then

$$\frac{\frac{\partial Y}{\partial X_1} \bullet X_1}{Y} = \frac{A\alpha X_1^{\alpha-1} X_2^{\beta} \bullet X_1}{AX_1^{\alpha} X_2^{\beta}} = \alpha \qquad \text{(E 3.6)}$$

Therefore, α is the relative distributive share of input X_1, and β has the same feature, too.

3.4 Empirical model development (time-invariant model)

Stochastic frontier models were introduced by Aigner, Lovell and Schmidt (1977). Stochastic frontier models are now common in many different econometric applications. The empirical stochastic frontier production models utilized in this study are originally derived in Fan (1990), Battese and Coelli (1992), and Kumbhakar and Lovell (2000). The basic idea of estimation of a stochastic production frontier model is that the estimates for input elasticity are estimated by maximum likelihood estimation (MLE); the production frontier is estimated and bounds the data from above by MLE excluding uncontrollable random shock; and technical efficiency is predicted by measuring the distance between the real output and the estimated frontier.

There are two types of stochastic frontier models: time invariant and time varying. Only the former type is used in this study. The results from the time-invariant stochastic frontier model are explained in detail.

As indicated above, for this study the Cobb-Douglas functional form is used as the basis for the stochastic frontier analysis. The function must be estimated with various restrictions. For example, on the interaction between inputs and technological progress, namely time (t), is separable. Assuming that the two random residuals (v_i and u_i) take the exponential form, the empirical model can be written as follows

$$Y = \beta_0 x_{it}^{\beta_{it}} e^{\beta_{it}} e^{v_{it}} e^{-u_{it}} \tag{E 3.7}$$

The logarithm form of (E 3.7) is

$$\ln(Y) = \ln\beta_0 + \sum_{i=1}^{n} \beta_{it} \ln(x_{it}) + \beta_{it} t + v_{it} - u_{it} \tag{E 3.8}$$

where i denotes the ith provinces or regions, and t denotes time t;

Y_{it} is the realized output, measured as gross value of agricultural output;

x_{it} is $(1 \times k)$ row vectors of inputs including agricultural labor, sown area, irrigated area, chemical fertilizer and machinery as so on;

$\beta_0 x_{it}^{\beta_{it}} e^{\beta_{it}} e^{v_{it}}$ is potential output or production frontier;

v_{it} represents the uncontrolled random shocks;

u_{it} represents the one-sided non-negative random shocks due to technical inefficiency; and the production technical efficiency $TE_{it} = \exp(-\hat{u}_{it})$ and the values of TE_{it} are indeed between 0 and 1.

The production function is estimated using maximum likelihood. Note that the maximum likelihood estimation (MLE) of equation (3.7) requires strict assumptions. Distributional assumptions on the residual components in the stochastic frontier model (E 3.8) are:

$v_{it} \sim N(0, \sigma_v^2)$, which means v_{it} has normal distribution with mean 0 and variance σ_v^2;

$u_{it} \sim N^+(\mu, \sigma_u^2)$, which is a non-negative truncated distribution with mean μ and variance σ_u^2. When $\mu = 0$, $u_{it} \sim N^+(0, \sigma_u^2)$, which is a special case of the previous distribution.

v_{it} and u_{it} are independently distributed of each other, and of the regressors.

The density function of u, which is independent of time in time-invariant model, is:

$$f(u)=\frac{2}{\sqrt{2\pi}\sigma_u[1-\phi(-\mu/\sigma_u)]}\cdot\exp[-\frac{(u-\mu)^2}{2\sigma_u^2}]. \tag{E 3.9}$$

The density function of v, which is dependent of time, is:

$$f(v)=\frac{1}{(2\pi)^{T/2}\sigma_v^T[1-\phi(\mu/\sigma_u)]}\cdot\exp(-\frac{v'v}{2\sigma_v^2}), \tag{E 3.10}$$

where $v=(v_1,\ldots,v_T)'$

Therefore, the joint density function of u and v is:

$$f(u,v)=\frac{2}{(2\pi)^{(T+1)/2}\sigma_u\sigma_v^T[1-\Phi(-\mu/\sigma_u)]}\cdot\exp[-\frac{(u-\mu)^2}{2\sigma_u^2}-\frac{v'v}{2\sigma_v^2}]. \tag{E 3.11}$$

The joint density function of u and $\varepsilon=(v_1-u,\ldots,v_T-u)'$ is:

$$f(u,\varepsilon)=\frac{2}{(2\pi)^{(T+1)/2}\sigma_u\sigma_v^T[1-\Phi(-\mu/\sigma_u)]}\cdot\exp[-\frac{(u-\mu_i^*)^2}{2\sigma_*^2}-(\frac{\varepsilon'\varepsilon}{2\sigma_v^2}+\frac{\mu_i^{*2}}{2\sigma_*^2})], \tag{E 3.12}$$

where $\sigma_*^2=\dfrac{\sigma_u^2\sigma_v^2}{\sigma_v^2+T\sigma_u^2}$, in T periods of time;

$\mu_i^*=\dfrac{\mu\sigma_v^2-T\bar{\varepsilon}\sigma_u^2}{\sigma_v^2+T\sigma_u^2}$, and u_{it} is under truncated-normal assumption.

$\bar{\varepsilon}=\dfrac{1}{T}\sum_t\varepsilon_{it}$, where $\varepsilon_{it}=v_{it}-u_{it}$.

Note: if $\mu=0$, $\mu_i^*=\dfrac{T\bar{\varepsilon}\sigma_u^2}{\sigma_v^2+T\sigma_u^2}$, and u_{it} is under half-normal assumption.

Therefore, the density function of ε is

$$f(\varepsilon)=\int_0^\infty f(u,\varepsilon)du$$

$$=\frac{2[1-\Phi(-\mu_i^*/\sigma_*)]}{(2\pi)^{T/2}\sigma_v^{T-1}(\sigma_v^2+T\sigma_u^2)^{1/2}[1-\Phi(-\mu/\sigma_u)]}\cdot\exp[-(\frac{\varepsilon'\varepsilon}{2\sigma_v^2}+\frac{\mu_i^{*2}}{2\sigma_*^2})] \tag{E 3.13}$$

$\Phi(\cdot)$ represents the distribution function for the standard normal random variable.

Thus, the density function of the conditional distribution $(u\mid\varepsilon)$ in time-invariant model is

$$f(u \mid \varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{(2\pi)^{1/2}\sigma_*[1-\Phi(-\mu^*/\sigma_*)]} \cdot \exp[-\frac{(u-\mu^*)^2}{2\sigma_*^2}], \qquad \text{(E 3.14)}$$

which is $N(\mu_i^*, \sigma_{i*}^2)$ distributed with the positive truncation, when $\mu \neq 0$.

The conditional expectation of $\exp(-u_i)$ is

$$E[\exp(-u_i) \mid \varepsilon_i] = \int_0^\infty \exp(-u_i) f(u_i \mid \varepsilon_i) du_i$$

$$= \frac{1-\Phi[\sigma_* - (\mu_i^*/\sigma_*)]}{1-\Phi(-\mu_i^*/\sigma_*)} \cdot \exp(-\mu_i^* + \frac{1}{2}\sigma_*^2) \qquad \text{(E 3.15)}$$

It is known that $TE_{it} = \exp(-\hat{u}_{it})$, so

$$TE_i = \frac{1-\Phi[\sigma_* - (\mu_i^*/\sigma_*)]}{1-\Phi(-\mu_i^*/\sigma_*)} \cdot \exp(-\mu_i^* + \frac{1}{2}\sigma_*^2) \qquad \text{(E 3.16)}$$

The estimates, $\beta, \sigma_v^2, \sigma_u^2$ and μ, in the time-invariant model can be obtained by maximizing the log likelihood function, derived from the density function of ε. The log likelihood function with N observations in T time periods is

$$L(\beta', \sigma_v^2, \sigma_u^2, \mu; y) = -\frac{1}{2}(\sum_{i=1}^{N} T_i)\ln(2\pi) - \frac{1}{2}\sum_{i=1}^{N}(T_i - 1)\ln(\sigma_v^2) - \frac{1}{2}\sum_{i=1}^{N}\ln(\sigma_v^2 + \sigma_u^2)$$

$$- N\ln[1-\Phi(-\mu/\sigma_u)] + \sum_{i=1}^{N}\ln[1-\Phi(-\mu_i^*/\sigma_{*i})]$$

$$-\frac{1}{2}\sum_{i=1}^{N}(\frac{\varepsilon_i'\varepsilon_i}{\sigma_v^2}) - \frac{1}{2}N(\mu/\sigma_u)^2 + \frac{1}{2}\sum_{i=1}^{N}(\mu_i^*/\sigma_i^*)^2$$

3.5 Summary of this chapter

Several theories and models, which are utilized this study, have been explained in this chapter. The effect of institutional and policy reforms on the Chinese agricultural production is measured as an improvement in production efficiency. In order to estimate the improvement in production efficiency in the Chinese agricultural sector, a frontier production function is utilized, as was explained in the subsection 3.3. The technological progress is modeled in the empirical model as the "time term" (t), which was developed in the subsection 3.2. The frontier production function with a Cobb-Douglas functional form will be estimated using MLE.

Chapter 4 Data description

4.1 Data description and adjustment

The data for the agricultural outputs and inputs in this thesis include only primary agricultural activities, that is farming, forestry, fishery, animal husbandry and related sideline production activities. The data excludes any off-farm activities, such as rural industries and service-related activities. The year 1952 is used as the beginning year for this study because the land reforms (land confiscation and redistribution) had finished and the Chinese agricultural sector had recovered from the World War II and the Civil War by 1952. The end year is the year 2005. The set of data is nation-based data, and is not used in the empirical estimation in chapter 5. Some figures are drawn according to the national data.

The beginning year is 1981 for provincial data, because the data are not available before 1981 since China's statistical bureaus were established after 1980, but this deficiency does not significantly influence the study's objectives. The provincial data are available for 29 provinces. For consistency, two new provinces of 31 provinces, Hainan and Chongqing, are combined with their old provinces, Guangdong and Sichuan, because they were separated and became two new provinces and a province-level city in the latter time. As to regional data, they are the summations of provincial data for each region. The major empirical analysis in this study is focused on great western development, which is a regional reform in the west of China, so the provincial data are divided into two regions, the west (11 provinces) and the east (18 provinces). The empirical estimation only involves the data from 1990 to 1999.

A. Gross Value of agricultural output (GVAO) (unit: 100 million yuan):

   The national data are from the Economic Research Service (ERS) in the U.S. Department of Agriculture and the GVAO for the last year 2005 is from the China's Statistical Yearbook 2006. Provincial data (1981-2005) are from the China's statistical yearbook of various years and different provincial statistical yearbook. The values are based on current prices in real terms. GVAO is the summation of the output values of farming, forestry, fishery, animal husbandry and sideline activities:

   A.1. Farming (unit: 100 million yuan): the data are from ERS, and the China Statistical Yearbook 2006. (The sources for A.2, A.3 and A.4 are the same.)

   A.2. Animal husbandry (unit: 100 million yuan)

   A.3. Forestry (unit: 100 million yuan)

   A.4. Fishery (unit: 100 million yuan)

B. Agricultural inputs: Agricultural inputs in this study include labor, land, chemical fertilizer, machinery and irrigation. Most of the data are from ERS, the various issues of the China's Statistical Yearbook and various provincial statistical yearbooks. The details of statistics on these agricultural inputs are as follows:

B.1. Labor (unit: million persons): Labor input is measured as the number of persons who are directly engaged in agricultural production, including farming, animal husbandry, forestry, fishery and sideline activities at the end of year, which means the labor in rural industry is excluded.

B. 2. Land (unit: 10,000 hectares): Land input is measured by the total sown area at the end of the year, which is more accurate and larger than arable land because land generally is sown more than one times a year. Sown area is area of land on which sow and harvest take place.

B.3. Irrigation (unit: 10,000 hectares): Irrigation input is measured by the total irrigation area at the end of the year in agriculture.

B.4. Chemical fertilizer (unit: 1000 tons): Chemical fertilizer input includes ammonium sulfate, super-phosphate and potassium sulfate.

B.5. Machinery power input (unit: 10000kw): It is measured as the total horse power of machinery engaged in farming, animal husbandry, forestry, fishery and sideline activities such as plough, irrigation, harvest, agricultural transportation and so on. Most of the data before 1978 are not available, so I estimate them by the same method described in the part B.4 and also according to the data of those years in Fan's paper (1997).

C. Partial factor productivities, namely average production--the data are directly obtained from the various issues of China's Statistical Yearbook.

C.1. Partial land productivity: output/land. (kg/hectare)

C.2. Partial labor productivity: output/labor (kg/agricultural labor)

C. Agricultural output per capita (kilogram per capita): It is measured by the total agricultural output over population. It includes grain output per capita, cotton output per capita, output of oil-bearing crops per capita, output of pork, beef and mutton per capita and output of the total aquatic products per capita.

4.2 Data analysis

The data are analyzed further in this section by some simple computations and graphs, so the influences of the reforms on Chinese agricultural production can be shown and predicted.

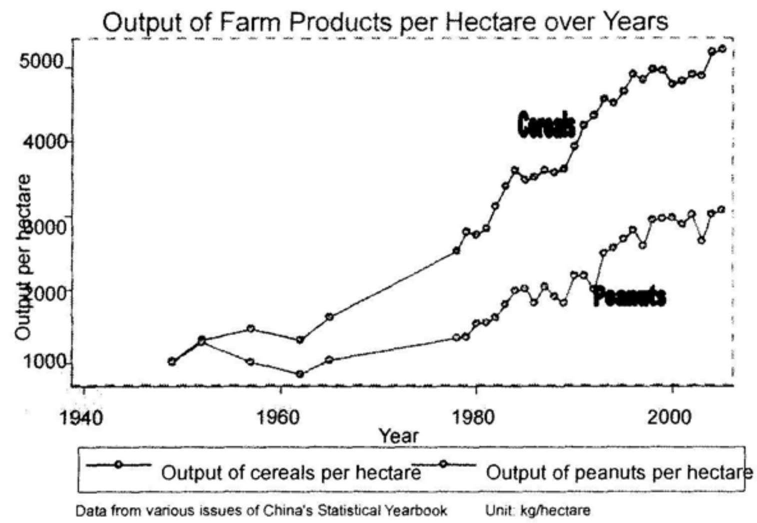
4.2.1 The effects of the two institutional reforms on the partial productivities in the Chinese agricultural sector

Labor and land are major factors in agricultural production. Therefore, the partial productivity improvement of labor and land significantly indicates progress of the production efficiency, namely the effects of institutional reforms on agricultural production. Here only the data of some major agricultural products are picked for the analysis because of simplicity, but the typical paths of the effects on the partial productivities should not be compromised with the data.

The data of land and labor partial productivities of some major agricultural products in figure 4.1 and in figure 4.2 are directly collected from various issues of

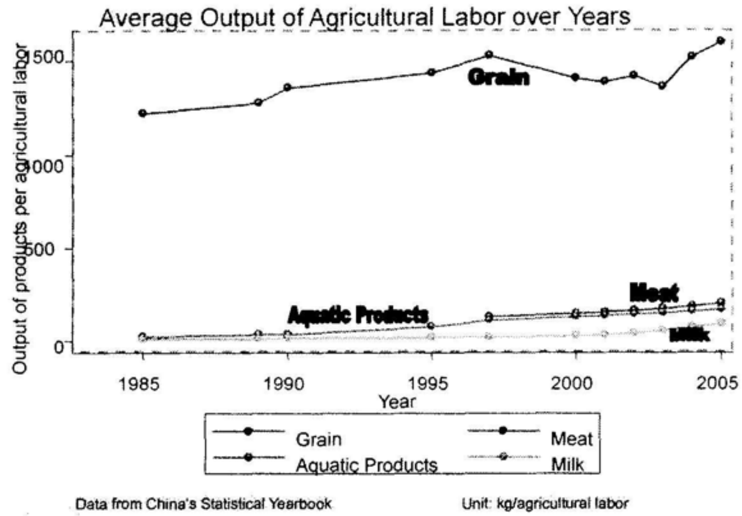
China's Statistics Yearbook.

Figure 4.1



As the figure 4.1 shows, the average yield of grain and peanuts decreased after the short-lived increase due to land reform, and were lowest from 1958 to 1962. Yields then slowly increased after the late beginning of 1960s. There is a stronger increase, which began in 1979, and land productivity continuously increased until the present. It demonstrates that institutional reforms after 1978 had positive effects on land productivities. There is no strong evidence in the figure showing that the WTO-accession had great impacts on yield. Both of the curves after 2001 are smooth. As some economists predicted, the joining the WTO is just an extension of the Reform and Openness policy (Huang, Rozelle & Zhang, 2000).

Figure 4.2



According to figure 4.2, average labor output of major agricultural products has been smoothly increasing in the past twenty years, and the increase is getting greater after 2000. Hence, the conclusion can be made that accession to the WTO has improved agricultural labor productivity. Of course, the improvement of the agricultural labor productivity can also be caused by the education of labor and the use of new technology. Because of the lack of the data before 1985, there is no way to determine the effects of 1978 reform on labor partial productivities of major agricultural products in this figure.

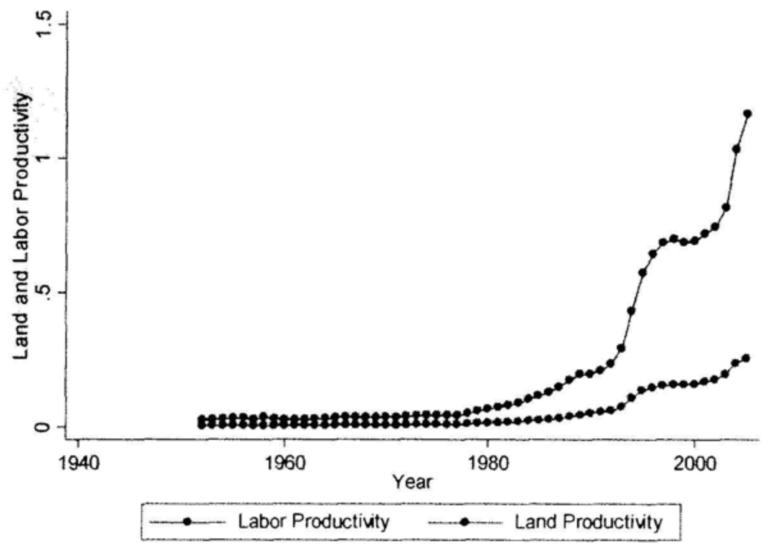
The above data are directly collected by the Chinese official statistics bureau and on some specific agricultural products. In the next, partial productivities of land and labor are calculated with available data of GVAO, sown area and number of labor in agriculture as

Land Partial Productivity = GVAO/sown area

Labor Partial Productivity = GVAO/number of laborers in agriculture

The results of the calculation in land and labor partial productivities are presented in figure 4.3. Since GVAO, sown area and number of labor in agriculture are the gross values, the increase of the two partial productivities indicates the effects of institutional reforms on them in the country as a whole.

Figure 4.3 Partial productivities of labor and land in China (100 yuan per capita, 10,000 yuan per hectare)



Data are from USDA and various issues of China's statistics yearbook. The top line is for labor productivity and the bottom line is for land productivity.

As figure 4.3 shows, the partial productivities of land and labor are unchanged before 1978. The two partial productivities increased sharply after 1978 and there is a steeper increase in the two partial productivities after 2001, which means that efficiencies of labor and land markedly improved after the 1978 reform.

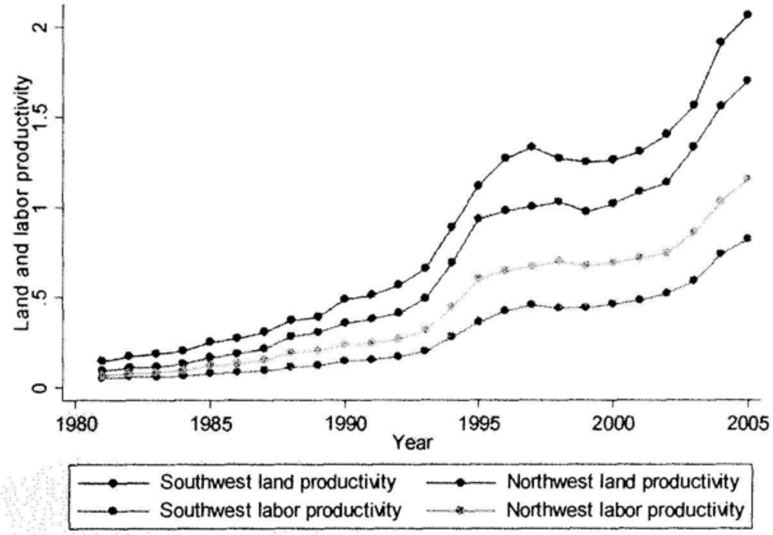
Comparing the two partial productivities in the figure 4.3, the increase of labor partial productivity is steeper than the increase of land partial productivity after 1979 reform. In another words, the efficiency of labor improved faster than the efficiency of land. This is because the improvement of land productivity is more limited than the improvement of labor productivity. Agricultural labor has more incentive to work harder after the 1978 reform because of the closer relationship between income and effort. However, introducing new technologies may improve land efficiency, but the improvement may not be substantial.

In sum, the partial productivities of land and labor have been growing sharply since 1978. Therefore, the 1978 reforms and accession to the WTO have had some fundamental influences on land and labor efficiencies.

4.2.2 The effects of great western development on partial productivity in western region

Data used in this subsection are from various issues of provincial statistical yearbooks. Two sets of partial productivities (labor and land productivities) are calculated by the two formulas in the subsection 4.2.1. The results are graphed and presented in figure 4.4.

Figure 4.4 Partial productivities of labor and land over time in the two west regions (100 yuan per capita, 10,000 yuan per hectare).



Data are from various years and provincial statistical yearbooks. The first line is for southwest land productivity; the second line is for northwest land productivity; the third line is for northwest labor productivity; and the last line is for southwest labor productivity.

The figure 4.4 presents two major productivities of land and labor in the two western regions, northwest and southwest. There is quick jump around 1995, mid-1990s, which is about the time of executing great western development. A slow drop occurred in the late 1990s, but the values of partial productivities are still greater than the values before great western development. The Chinese government continues to push great western development, so there is a continuous increase in both partial productivities and in both western regions. However, the increase of labor productivities is smaller than the increase of land productivities in both western regions. In a word, great western development has had positive impacts on two major agricultural productivities, land and labor productivities, in the western regions.

4.3 Summary of this chapter

Data which are used for each regression and analysis in this study are carefully described in this chapter. The data are collected in different levels such as country, regional and provincial, including all specific data in the country as a whole, six divided regions and 29 provinces of China.

Partial productivities of land and labor are calculated through simple calculations and graphed in figures. The influences of the 1978 reform, accession to the WTO and the great western development can be identified in the figures.

Chapter 5 Estimation and empirical results

5.1 Variable explanation and summary

The production performance is explained in terms of five inputs, neutral technological improvement and technical efficiency (impacts of the reforms). Descriptive statistics for the output and input variables is presented in the table 5.1.

Table 5.1 Description of output and input variables

Variable Name	**Description (unit)**
Dependent variable:	
GVAO	Gross value of agricultural output (100 million yuan)
Independent variables:	
Irri	Irrigated area (10000 hectares)
Sown	Sown area (10000 hectares)
Chem	Total consumption of chemical fertilizer (1000 tons)
Labor	Agricultural employment (million persons)
Mach	Total power of agricultural machinery (10000 kw)

The summary statistics on different variables in the frontier production function or modeling technical production efficiency, are presented in the table 5.2 (national data), and the table 5.3 (provincial data).

Table 5.2 Summary statistics for variables in the whole country from 1981 to 2005

Variable	Obser-vation	Sample Mean	Standard Deviation	Minimum Value	Maximum Value
GVAO	150	2582.625	2632.737	156.12	12185.8
Agricultural Labor	150	5299.036	3092.357	1301.1	9794.6
Sown Area	150	2495.359	969.394	1315.68	4107.96
Irrigated Area	150	815.608	403.6999	202.3	1648.56
Chemical Fertilizer	150	516.1059	360.158	67.5	1454.2
Machinery	150	613.0569	421.299	164.11	2130.75

Table 5.3 Summary statistics of variables for the east and the west from 1990 to 1999

Variable	Obser-vation	Sample Mean	Standard Deviation	Minimum Value	Maximum Value
West (11 provinces pre-reform, 1990-1994)					
GVAO	55	4.913	1.122	2.845	7.114
Agricultural Labor	55	6.339	1.209	4.453	8.374
Sown Area	55	5.552	1.146	3.061	7.151
Chemical Fertilizer	55	3.52	1.335	0.399	5.431
Irrigated Area	55	3.77	0.926	1.513	5.01
Machinery	55	4.363	1.056	2.098	5.66
West (11 provinces post-reform, 1995-1999)					
GVAO	55	5.709	1.143	3.581	7.518
Agricultural Labor	55	6.369	1.169	4.464	8.289
Sown Area	55	5.624	1.155	3.088	7.195
Chemical Fertilizer	55	3.883	1.315	0.405	5.639
Irrigated Area	55	4.074	0.901	1.766	5.378
Machinery	55	4.476	0.995	2.693	5.725
East (18 provinces pre-reform, 1990-1994)					
GVAO	90	5.8	0.814	4.006	7.235
Agricultural Labor	90	6.663	1.173	4.138	7.988
Sown Area	90	6.044	0.974	3.983	7.097
Chemical Fertilizer	90	4.516	0.977	1.932	5.872
Irrigated Area	90	4.678	0.714	2.896	5.936
Machinery	90	4.982	0.842	3.372	6.14
East (18 provinces post-reform, 1995-1999)					
GVAO	90	6.655	0.812	4.892	7.711
Agricultural Labor	90	6.635	1.163	4.179	8.101
Sown Area	90	6.048	0.998	3.965	7.144
Chemical Fertilizer	90	4.766	0.987	2.501	6.039
Irrigated Area	90	4.915	0.841	2.745	6.496
Machinery	90	5.026	0.864	3.314	6.175

The summary statistics in the table 5.2 are for the country as a whole. It indicates that over 30% of land was irrigated in the whole country. As the standard deviation in the table 5.2 shows, the input variables, agricultural labor, sown area and irrigated area, varied the least. This is probably because land is a limited resource and labor usage will decline with the improvement of agricultural technology and agricultural efficiency. The input variables, chemical fertilizer and machinery, changed by a greater degree, because the government's control on chemical fertilizer was removed, which means that fertilizer was available on the free-market, and newly introduced and imported technology required more machinery. The output or dependent variable, gross value of agricultural output (GVAO), varied the most, because of the increasing prices and production of agricultural goods.

Comparing the statistics between the west and the east, and before and after great western development, the western region has relatively lower GVAO and more input consumption. There is no large increase or decrease of the input variables, and GVAO in both regions has increased a lot.

5.2 Hypothesis and estimation procedure

In order to support the thesis objective stated in section 1.2, two steps should be taken:

(1) Establish that the great western development reform has influenced agricultural production and productivity, and calculate the level of

influence is in terms of technical efficiency.

(2) Establish that the great western development reform has caused technical efficiency to improve faster in the west than in the east.

Therefore, the hypothesis of this thesis is that the change in technical efficiency between the pre-reform and post-reform period for the west is insignificant, and it is the same for the eastern region and the western region. The alternative hypothesis is that the change in technical efficiency from pre-reform to post-reform in the west is statistically significant, and is greater than in the east. The mathematical form of the hypothesis can be written in two parts as follows,

1) The significance of the change in technical efficiency between pre-reform and post-reform in the west:

$$H_0 : TE_{post}^{west} - TE_{pre}^{west} = 0$$

$$H_a : TE_{post}^{west} - TE_{pre}^{west} > 0$$

2) The technical efficiency has improved faster in the west than in the east:

$$H_0 : TE_{post}^{west} - TE_{pre}^{west} = TE_{post}^{east} - TE_{pre}^{east}$$

$$H_a : TE_{post}^{west} - TE_{pre}^{west} > TE_{post}^{east} - TE_{pre}^{east}$$

Ideally, the null hypothesis should be rejected with 95% confidence, which will be performed in the section 5.4. Such a rejection would allow one to conclude that the gain in productivity in the west exceeded the gain in productivity in the east as a result of the great western development reform.

Before the hypothesis test, coefficients of agricultural inputs and technical efficiency should be estimated. The whole country is divided into 2 regions, the west and the east. The same estimation procedure is used for the western and the eastern provinces. STATA command "xtfrontier ln(output) ln(inputs), i(provinces) t(year) ti" for the time-invariant stochastic frontier production model with panel data is used for the estimation for both regions. Command "predict TE, te" is used to predict technical efficiency for each province in both western and eastern regions for the pre-reform and post-reform periods, which are presented in table 5.6 and 5.7. I subtract the technical efficiency in the post-reform periods to those in the pre-reform periods for the change rates of technical efficiency, which are presented in the last columns of table 5.6 and 5.7. Then I use the command "summary TE" to obtain the average level of technical efficiency of the eastern and western regions for the two periods and also the average level of the change rates, which are presented in the bottom rows of table 5.6 and 5.7. At last, comparing the average change rates of technical efficiencies for the western provinces to those for the eastern provinces, the effects of the western reform are identified. Estimation results are presented in the next section.

5.3 Estimation results

The time-invariant stochastic frontier model, as given by equation (E 3.8), is estimated using panel data with five agricultural inputs (labor, sown area, irrigated area, chemical fertilizer and machinery). The independent variable is gross value of agricultural output. The model is estimated without a time trend because the estimation procedure does not converge with the inclusion of the time variable. We only consider a subset of the data for the years around mid-1990s, when the western reform took place. The pre-reform period is from 1990 to 1994, and the post-reform period is 1995 to 1999. The equation to be estimated can be written as

$$\begin{aligned}\ln(GVAO) = const + \beta_1 \ln(Sown) + \beta_2 \ln(Labor) \\ + \beta_3 \ln(Chem) + \beta_4 \ln(Mach) \\ + \beta_5 \ln(Irri) + v_i - u_i\end{aligned}$$

Technical efficiencies, $\exp(-\hat{u}_i)$, present the effects of policy and institutional reforms. The estimated coefficients of the agricultural inputs, $\hat{\beta}_1,\ldots,\hat{\beta}_5$, represents how much gross value of agricultural output will change, when the agricultural inputs increase one unit (both in the logarithm scale). Further, the coefficients of the agricultural inputs demonstrate the output elasticity coefficients for inputs and the relative distributive shares of inputs, according to the explanation of Cobb-Douglas function in the subsection 3.3.3.

Values of the parameter estimates in the time-invariant model for the western and eastern provinces are presented in the table 5.4 and 5.5, respectively. The starred values indicate that the estimate is significant at the 95 percent confidence level.

Table 5.4 Estimates of time-invariant models for the western provinces

	11 western provinces from 1990 to 1994 (55 observations)	11 western provinces from 1995 to 1999 (55 observations)
Regression	Frontier (TI)	Frontier (TI)
Constant	3.793*	0.095
lnSown	-2.058*	-0.06
lnLabor	0.519	0.457*
lnChem	0.932*	0.043
lnIrri	0.231	0.428*
lnMach	1.58*	0.279*
Wald Chi2	190.49	2343.92
$\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$	0.2275264*	0.0453082*
$\gamma \equiv \sigma_u^2 / \sigma^2$	0.938895*	0.882351*
μ	0.9711858*	0.05416
Log-likelihood	16.224171	51.116653

* indicate the estimates are statistically significant in 95% confidence interval.

Table 5.5 Estimates of time-invariant models for the eastern provinces

	18 eastern provinces from 1990 to 1994 (90 observations)	18 eastern provinces from 1995 to 1999 (90 observations)
Regression	Frontier (TI)	Frontier (TI)
Constant	3.79*	3.0582*
lnSown	-0.66*	0.176
lnLabor	-0.167	0.021
lnChem	1.527*	0.428*
lnIrri	-0.291	0.148
lnMach	0.484*	0.034
Wald Chi2	187.61	165.21
$\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$	0.121*	0.076*
$\gamma \equiv \sigma_u^2 / \sigma^2$	0.682*	0.918*
μ	0.591*	0.539*
Log-likelihood	-2.165	65.388

* indicate the estimates are statistically significant in 95% confidence interval.

According to the estimates stated above, sown area has negative effects on the agricultural production except for the one for the east in the pre-reform period, which is positive and insignificant, which is not expected. Most of other inputs have positive effects on agricultural production, which is consistent with economic theory, except for the ones of labor and irrigated area for the east in pre-reform period, which are negative and insignificant. In theory, the more agricultural inputs are used, the more agricultural output is produced.

However, only one of the four coefficients for labor and irrigated area is significant. Labor is increasingly unimportant in modern agricultural production thanks to the introduction of new technology. As to irrigated area, it is correlated with sown area, so a part of its effects is absorbed by sown area. The significant coefficients of labor and irrigated area are for the west in the post-reform period. It can be explained that the great western development reform has made labor and irrigation more efficient. Three of four coefficients for machinery and chemical fertilizer are positive and statistically significant. This is because more and more new technologies are introduced into the Chinese agricultural sector, so more and more machinery has to be used for the new technologies. Chemical fertilizer has been a very important factor of agricultural production growth since Reform and Openness, after which control of the usage of chemical fertilizer was relaxed.

According to the Wald Chi² values, the four regressions fit well. It is known that $\gamma \equiv \sigma_u^2/\sigma^2$. Then γ s are statistically significant in the four regressions, which means that the agricultural production is not fully technically efficient in the west and the east of China before and after great western development reform. This is because, if γ is significant, then σ_u^2 is significant, which implies technical inefficiency is significant. At last, four μ s are positive and three of them are statistically significant, which means that technical inefficiency has positive and truncated distribution, except for the one for the west in the post-reform period, which means that the technical inefficiency has half-normal distribution.

Estimates of technical efficiency for two distinct time periods are derived using equation (E 3.16). The TE estimates for the two time periods are separately reported for the western and eastern provinces. The results are presented in the table 5.6 and 5.7 respectively.

Table 5.6 Technical efficiencies for time-invariant models in the west

11 western provinces	Technical efficiencies from 1990 to 1994	Technical efficiencies from 1995 to 1999	Change in TE parameters for the two periods
Guangxi	0.2553244	0.9713097	0.7159853
Sichuan	0.4556521	0.9027787	0.4471266
Guizhou	0.8991675	0.9218419	0.0226744
Yunnan	0.2840122	0.7183173	0.4343051
Tibet	0.6471313	0.9620322	0.3149009
Shaanxi	0.2690791	0.714372	0.4452929
Gansu	0.3013313	0.7815136	0.4801823
Qinghai	0.2976564	0.798196	0.5005397
Ningxia	0.2036223	0.6717466	0.4681243
Xingjiang	0.3433059	0.9492281	0.6059222
Inner Mongolia	0.5717947	0.8657714	0.2939767
Average	0.4116434	0.8415552	0.4299118

Table 5.7 Technical efficiencies for time-invariant models in the east

18 eastern provinces	Technical efficiencies from 1990 to 1994	Technical efficiencies from 1995 to 1999	Change in TE parameters for the two periods
Beijing	0.4340143	0.5511612	0.1171469
Tianjin	0.836676	0.5102639	-0.3264121
Hebei	0.4392591	0.5178464	0.0785873
Shanxi	0.3637953	0.3057621	-0.0580332
Liaoning	0.5330722	0.7252834	0.1922112
Jilin	0.4396498	0.5004902	0.0608404
Heilongjiang	0.6721576	0.4808757	-0.1912819
Shanghai	0.3844868	0.6718609	0.2873741
Jiangsu	0.4849817	0.6559654	0.1709837
Zhejiang	0.691915	0.7900981	0.0981831
Anhui	0.5844431	0.4854478	-0.0989953
Fujian	0.5057752	0.7920493	0.2862741
Jiangxi	0.8860925	0.5027583	-0.3833342
Shandong	0.4644925	0.6292994	0.1648069
Henan	0.4740714	0.5081925	0.0341211
Hubei	0.561687	0.512765	-0.048922
Hunan	0.8104662	0.599565	-0.2109011
Guangdong	0.6384006	0.9426891	0.3042885
Average	0.5669687	0.5934652	0.0264965

Comparing the two sets of technical efficiencies in the table 5.6 and 5.7, it would appear that the great western development has had a highly significant and positive impact on agricultural productivity in the west of China. Indeed, the average level of technical efficiency has risen from 0.41 to 0.84 due to the western reform. On the other hand, the average change in technical efficiency is only 0.026 in the same time period without the influence of the western reform. However, it cannot be concluded that the great western development policy has made the western region keep up with or even exceed the eastern region as the table 5.6 and 5.7 shown, because the estimated technical efficiency is from two different sets of regressions.

Also the increase of technical efficiency is probably caused by compositional improvements among agricultural products. Great western development policy includes improving agricultural production structure (see section 2.2.3), which means the increase of technical efficiency is not only due to producing more efficiently but also because of producing more efficient agricultural products in place of those less efficient. Termination of grain self-sufficiency policy makes agricultural production structure more efficient, too. The provinces, which have disadvantages in grain production, do not have to produce grain and instead produce agricultural products that they can benefit more from. According to provincial data, 30.6% of GVAO in Inner Mongolia is contributed by animal husbandry in 1992, and the percentage increased to 33.2% in 1998 (data from Statistics Yearbook 1992 and 1998).

5.4 Hypothesis test

In order to formally test the null hypothesis presented in section 5.2, it is necessary to conduct further statistical analysis. In particular, the null hypothesis that the great western development reform had equal influence on agricultural productivity in the west and the east can be rejected if the following conditions hold: the difference in the technical efficiency parameter across the pre-reform and post-reform period is statistically different from zero in the west and is not statistically different from zero in the east. Unfortunately, there is no direct way to conduct such an empirical test using standard programming techniques. This implies that Monte Carlo techniques must be utilized. The procedures of Monte Carlo method for the hypothesis test are as follows,

1) The values of σ_u^2, σ_v^2 and μ are known from above four regressions.

   For the western region from 1990 to 1994, $\sigma_u^2 = 0.082173$, $\sigma_v^2 = 0.038345$ and $\mu = 0.591265$. For the western region from 1995 to 1999: $\sigma_u^2 = 0.07017$, $\sigma_v^2 = 0.006258$ and $\mu = 0.538866$.

   For the eastern region from 1990 to 1994: $\sigma_u^2 = 0.213623$, $\sigma_v^2 = 0.013903$ and $\mu = 0.971186$. For the eastern region from 1995 to 1999: $\sigma_u^2 = 0.039978$, $\sigma_v^2 = 0.039978$ and $\mu = 0.039978$.

2) Randomly draw v_{it} and u_{it}.

   Based on the ideas of Dhrymes (2005), the truncated normal distribution is $N(0,\sigma_u^2)$, and the variance of u_{it} is $\sigma_u^2 = \frac{\pi}{2}\mu^2$. The normal distribution is $N(0,\sigma_v^2)$. Dhrymes (2005) believes that

   $E(\mu \mid \mu < 0) = \mu - \sigma \frac{\phi(u)}{\Phi(u)}$. Thus,

$$E(\mu \mid \mu < 0) = 0 - \sigma \frac{\phi(0)}{\Phi(0)}$$

$$= -\frac{\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(0)^2}}{\frac{1}{2}} \sigma$$

$$= -\frac{2}{\sqrt{2\pi}} \sigma$$

   Then, $\sigma = \frac{\sqrt{2\pi}}{2} \mu$, for $\mu > 0$.

   Now the distributions of v_{it} and u_{it} are known, and then the values of them can be randomly drawn using EXCEL program.

3) Generate new values for the dependent variable, $\ln(GVAO)_{new}$, by the regression model in EXCEL,

$$\begin{aligned}\ln(GVAO)_{new} = const + \beta_1 \ln(Sown) + \beta_2 \ln(Labor) \\ + \beta_3 \ln(Chem) + \beta_4 \ln(Mach) \\ + \beta_5 \ln(Irri) + v_i - u_i\end{aligned}$$

The values of $const, \beta_1,\ldots,\beta_5$ are estimated in the above four regressions. v_{it} and u_{it} are the random drawn residuals and technical inefficiencies in the step (2).

4) New technical efficiencies for each provinces are calculated by running the new regressions with new dependent variable, $\ln(GVAO)_{new}$. Then the new average of the new technical efficiencies for each new regression is easily computed.

5) Repeat the above procedures 40 times for each of the above four regressions. After that, there are 40 average technical efficiencies for each regression.

6) Draw overlaid histogram graphs of the two sets of average technical efficiencies for western and eastern regions, separately (see figure 5.5 and figure 5.6).

Figure 5.1 Overlaid histogram of average technical efficiencies for the western region

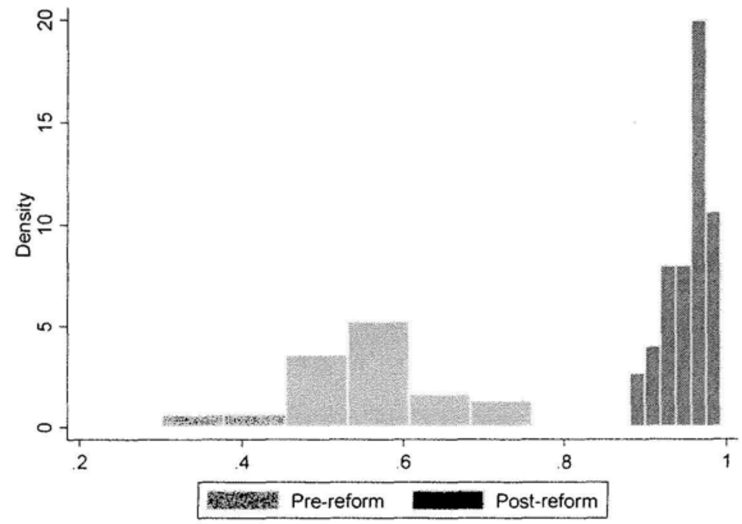
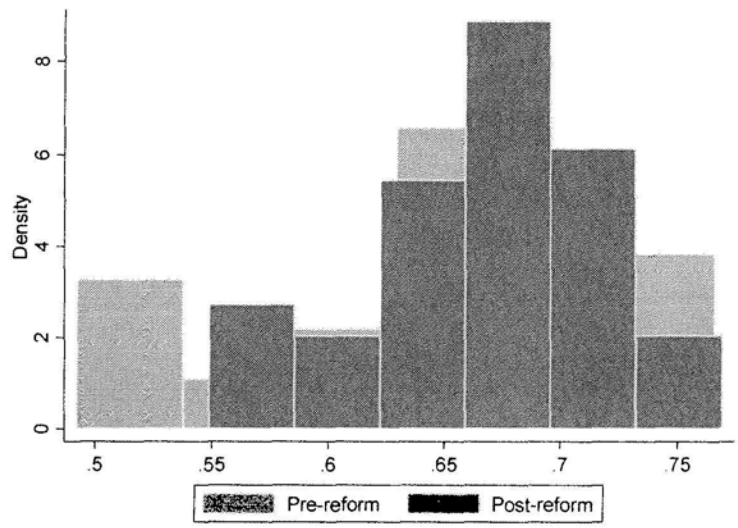


Figure 5.2 Overlaid histogram of average technical efficiencies for the eastern region



The distributions of average technical efficiencies in western region for pre- and post- reform periods are not overlaid to each other, but the distributions of average technical efficiencies in eastern region for pre- and post- reform periods are overlaid to each other. Therefore, the average increasing rate of technical efficiencies from pre-reform to post-reform for the western region is statistically significant, but the one for eastern region is not statistically significant.

In conclusion, the null hypothesis stated in the section 5.2 is rejected. The agricultural technical efficiency has improved faster in the west than in the east due to the great western development that took place in the west of China in mid-1990s.

5.5 Summary of this chapter

After the theory explanation and model development in the chapter 3, finally the empirical results are presented in this chapter. The main purpose of this chapter is to estimate empirically the effects of the great western development on agricultural production in China.

The technical efficiencies of various provinces in the western and eastern regions are predicted by the time-invariant model. The increasing rates of the technical efficiencies are calculated afterward. The Monte-Carlo method is used to test significance of the average increasing rates of technical efficiencies in the west and east of China. In conclusion, the great western development has had obviously positive effects on agricultural production in the west of China.

Chapter 6 Conclusion

6.1 Problems with the research in this study

Some problems, which occurred during the research process, are discussed in this subsection.

6.1.1 Problems with data

(1) Lack of data: missing and unmeasurable variables

Some observations are not available and are estimated by me, but I believe that the estimated figures are not far from the true values. Some variables are not measurable such as weather conditions, natural disasters and land quality and so on. As well, some input variables are missing from my models. Data for draught animals, used in agricultural production, are not available in the recent ten years, so the models in chapter 5 do not include this input variable.

(2) Reliability of data

Another concern with the data is reliability. The official data of Chinese agriculture are collected by the National Bureau of Statistics (NBS) and provincial bureau of statistics. The Chinese statistic system is based on "traditional bottom-up complete reporting systems", which creates a potential problem with data reliability due to the private targets of local governments. Macroeconomics data, such as agricultural output, growth rate, livestock inventory and fishery statistics and so no, are overstated, and unemployment rate, cultivated land and labor income are understated, according to many analysts' studies (Gale). Data reliability has improved in recent years because of assistance from other organizations, for example the United Nations Food and Agricultural Organization (FAO).

6.1.2 Problems with the models

(1) Unmeasured technological improvement:

Although each regression fits well in the chapter 5, the models are run without time trend variable, so neutral technological improvement cannot be separated with the technical efficiencies. Interaction terms between time and agricultural inputs are not included in the models, too, because of over-complication.

(2) Incomparable technical efficiency between two regions:

Another problem with the models is that I ran four separate regressions (see table 5.4 and 5.5), so I cannot conclude that the technical efficiency is greater in the west than in the east after the great western development policy was implemented in the west in mid-1990s. However, it is impossible to combine the four regressions into one regression. For further research, I could use a time-varying decay model to estimate technical efficiency for each year around the reform period and see if the same results would appear.

(3) Unidentifiable composition of agricultural production:

Compositional changes are likely to play an important role in the analysis. In other words, if because of the reforms the region shifts away from a mix of crops that are characterized by a low level of technical efficiency (TE) toward a mix of crops that are characterized by a high level of TE, then the estimate of TE will rise, even though the TE per crop has not changed. It is the same for composition of agricultural production among farming, forestry, animal husbandry and fishery. In my estimation, the composition cannot be identified. In further research, adding the composition proportions into the estimation model is a procedure that might make the estimates and technical efficiency more accurate.

6.2 Conclusion of this research

Agriculture is the base of a country and its industry. Better agricultural performance makes a country more stable. Agriculture also aids a country's industry. The share of agricultural production is getting smaller in Chinese total production, although the agricultural production is still increasing steadily, but agriculture is still a very important factor of Chinese economic growth (see table 1a in Appendix). China very large population requires stable agricultural growth.

Fan (1991) concluded that the increase of agricultural production is due to increased input use, technological change, institutional change and smoothing regional inequalities all working together. The impacts of the increased input use are estimated, but they are not the main purpose of this study. The main purpose of this study is to estimate how the institutional change and smoothing regional inequalities (great western development) affects agricultural production in the west of China.

After China's establishment in 1949, there were three agriculture related policy and institutional reforms in country-wide, which are land reform in late 1949, causing a 30-year-delay in China's economic development, Reform and Openness in late 1978, promoting the greatest economic development as well as uneven development between regions, and WTO-accession in 2001, creating a better trade environment. Great western development only took place in the western regions of China in order to narrow the economic gap between the western region and eastern coastal region. It is a preferential policy and institutional reform for the west of China.

The Chinese government, led by President Deng, finally realized that the institutional and market systems had to be reformed so as to push Chinese economy forward, and to encourage Chinese farmers and workers to work more efficiently. The reforms were initiated in late 1978. The Household Responsibility System (HRS) was introduced to substitute for the collective institution. The 1978 reform is the most successful institutional reform in Chinese history. Agriculture and industry have been soaring in China since the 1978 reform. However, this reform also caused a large economic gap between western and eastern regions.

The 1978 reform promoted the eastern coastal regions to become wealthy first. Due to poor natural conditions and the preferential policies of the 1978 reform, the economic gap between the west of China and the east of China became bigger than ever. The Chinese government, led by President Jiang, realized that correcting the uneven development is the next target of the Chinese economic development. The

Chinese government applied the policies and methods in the eastern coastal regions to the western regions, and widened the openness and strengthened the reforms in the west of China in the mid-1990s. This is the so-called great western development.

In order to demonstrate the effects of great western development numerically, a stochastic frontier production function was introduced and exploited. A time-invariant model is used to estimate the stochastic frontier production function and technical efficiencies empirically. Then the changes of the estimated technical efficiencies indicate the effects of the reforms.

A time-invariant model is used for the great western development to change the technical efficiencies in short time periods before and after the reform in the west of China and the east of China. By comparing the increasing rates of technical efficiencies for the west and the east of China in the same time periods, it is clear that great western development has significant and positive effects on agricultural production in the west of China. Since no reform has taken place in the east of China in the same time period, the increasing rate of technical efficiencies is not significant, which proves there is no reform at the national level influencing Chinese agricultural production. Therefore, the positive and significant increasing rate in technical efficiencies in the western region is solely caused by great western development.

The Chinese government realized the importance of smoothing the uneven development in China, and the positive results of the first stage of great western development. It is willing to push great western development deeper and wider. The State Council established a Leadership Group for Western China Development in January 2000, and even special laws and regulations were made for the western region such as those for preferential fiscal and taxation policies. Thus, further agricultural and industrial development is expected in the west of China.

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Appendix

Table 1a. Structure of Production in 1994

Table 1a has been removed due to copy right restrictions. The information removed is originally presented on page 94 of Wang and Hu (1999). The table presents that percentage of agriculture, industry and service in GDP, and their percentage of the labor force.

STATA code:

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