RESEARCH ON FACTORS OF AGRICULTURAL DEVELOPMENT AND PRODUCTION EFFICIENCY IN CHINA : FOCUSING ON HEBEI PROVINCE AND OTHER FIVE EASTERN PROVINCIAL-LEVEL REGIONS

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https://doi.org/10.15017/21694

出版情報：九州大学, 2011, 博士（農学）, 課程博士

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2012

Doctoral Dissertation

RESEARCH ON FACTORS OF AGRICULTURAL DEVELOPMENT AND PRODUCTION EFFICIENCY IN CHINA: FOCUSING ON HEBEI PROVINCE AND OTHER FIVE EASTERN PROVINCIAL-LEVEL REGIONS

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ABSTRACT

This study aims to analyze the impacts of component factors to gross agricultural growth and production efficiency of staple crops and individual farms in China; identify countermeasures to improve agricultural productivity, with sufficient, safe supply of agro-products; rational, efficient and proper application of production factors, and sustainable, friendly effects to the environment.

In Section 1, Chapter 1 introduces the background and objectives. The main points include the importance of identifying major factors contributing to China's agricultural growth in latest decades; significance of improving efficiency of agricultural production, in terms of sufficient and safe supply of agricultural products, due to the largest population and limited farmland, water, etc; the urgency of studying farmers' application of fertilizer and pesticides, in the dual impacts of agricultural chemicals on both supported agro-growth and menacing environmental and food safety simultaneously.

Being the principal part of this thesis, Section 2 is composed by series empirical analyses. Chapter 2 conducts a factor analysis of Chinese agriculture development in 1983-2006, from the perspectives of inputs change, institutional transition and technological progress. The result of C-D production function shows that increasing inputs of chemical fertilizer is the most important factor, following by technical progress, increased fixed assets, fiscal supports and transfer of agro-labors. In Chapter 3 and 4, production efficiency of wheat and corn in Hebei Province are measured, through an input-oriented DEA model with the assumption of Variable Return to Scale (VRS). Within the sampled counties, most of the farms are measured as in the status of increasing returns to scale. Outputs slacks show that comparing with technological adjustment, much margins lie in the socio-economic optimization. Meanwhile, different form liquid inputs, larger slacks exist amongst inputs connecting with agricultural infrastructure. Furthermore, Crosstabs Analysis confirms the significantly relating returns to scale of wheat and corn; as well as technical efficiencies and relating returns to scale within both wheat and corn; corn is more efficient than wheat production, while enlarging the farming scales is more important to the wheat. Using the similar DEA models, Chapter 5 develops a framework on agricultural production efficiency of individual farms. The data source is a survey to 99 household farms of Hebei province, conducted by the authors. Similarly, most of the inefficient farms can improve efficiency through enlarging their farming scales; ratios of net profit has a larger average slack to be increased than the absolute value; irrigation costs can be saved with the largest margin; large slacks exist in fertilizer and pesticides. The empirical analyses in the second stage indicate that reducing the numbers of agro-labor improve production efficiency; the public services do not improve the efficiencies, unless conducted together with farms' efficient access to the credit. In succession, Chapter 6 and 7 study farmers' behaviors and perceptions on applying agro-chemicals, including the total amounts, main components, possible consequences of over application, based on another survey of 560 household farms in six provincial regions of eastern China. Through the adoption of multivariate and binary logistic regression models, these two chapters identify the significance of enlarging farming scales, increasing farmer's migrant employment and incomes, in terms of their appropriate behaviors and perceptions on using agro-chemicals.

As the last section, in light of the proceeding findings and reviews of current status and prior literature, Chapter 8 raises comprehensive policy recommendations, concerning enlarging the farming scales, improving the contribution of agro-technology, promoting migrant employment of rural labors, channeling more funds to agriculture, increasing the value-added of agro-products, and strengthening public education and management on safe agro-production.

Keywords: C-D Production Function, Chinese Agriculture, DEA, Factor analysis, Production Efficiency

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Chapter 1 Introduction

1.1 Study background

On April 28, 2011, China National Bureau of Statistics released the Billiton of 6th National Census, according to which the total population of China has exceeded 1.37 billion in 2010. Being a country embracing the largest population, China highly needs the sufficient and safe supply of agricultural products, especially the grains. In recent years, Chinese government has adopted drastic innovations on agricultural institutions, including waved off the agro-taxation, increased the subsidies directly to grain-growing farmers, etc. Until 2009, the fiscal expenditure for agriculture, forestry and water conservancy amounts to 672.04 billion yuan, accounting for 8.81 percent in national public expenditure (CSY, 2010).

Meanwhile, the total area of arable land has dropped from 130.04 million *ha* in 1999 to 121.72 million *ha* in end of 2008 (CSY, 2010). In 2010, arable land per capita in China was 0.092 *ha*, only 40 percent of global mean (SCC, 2011). Since early 1980s, with the process of *Reforms and Opening-u*p, the number of agro-labors has been decreasing, thanks to the continuous shift of surplus labors to the urban areas and the other sectors. As the result, percentage of agro-labor in total labors dropped from 68.70 percent in 1980 to 38.10 percent in 2009. Nevertheless, comparing with the 10.35 percentage of agriculture in national GDP, surplus labors still exist in agriculture (CSY, 2010). Observing from the GDP per capita of the three strata of industries, value of primary industry (agriculture) was 11860 yuan, merely 16.31, 21.37 and 27.16 percent of the counterpart in secondary, tertiary industry and the total economy, respectively (Fig.1-1).

Considering the large population, especially the surplus labors hence relative low GDP per capita in agriculture and the limited or even diminishing arable land, it is of great importance to identify the significant determinants of agricultural development in latest decades. Furthermore, the measurement and hence improvement of agricultural production efficiency is essential to the whole economy, in terms of supplying enough food stuff and production materials. In addition to the macro-analysis of national and regional areas, micro-analyses are necessary from the perspective of individual household farms, which are the overwhelming production units in Chinese agriculture.

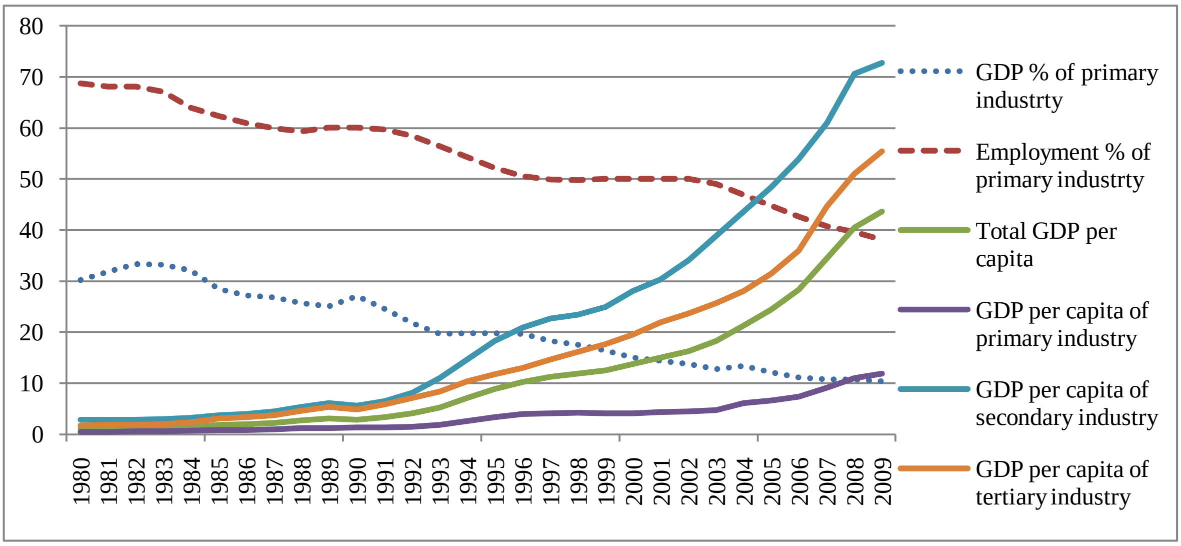

Fig.1-1 Share of agriculture in 1980-2009 (% and thousand *yuan*)

Source: China Statistical Yearbook, 2010

At the same time, the application of chemical fertilizers supported agro-growth in the first place (J. Y. Lin, 1992; D. Li, *et al* 2011b), and agro-pollution has become the first source of water pollution, due to over use of fertilizer and pesticides (CMEP, 2010). Simultaneously, the improper application of fertilizers and pesticides constitute major menaces to food safety (EB, 2010). Safe food apply originated from proper behaviors of agricultural production are the public appeals of both at home and abroad. In latest decades, especially after the entry of WTO in 2001, agricultural products are becoming the important goods for exportation. In 2000-2009, the value of exported agro-products has increased from 15.70 billion USD to 39.63 billion USD, maintained an annual growth rate of 10.84 percent (CMA, 2010). The high-quality exported agro-products are beneficial for improving the competitiveness of China in international market and thus farmers' incomes.

Therefore, it is necessary to study the application of agricultural chemicals of fertilizer and pesticides, in terms of their behaviors and perceptions. At present, as household farms are the overwhelming managing units of agricultural production, concerning studies should be conducted from the micro perspectives of the individual farms. Meanwhile, the impacts of significant factors to farms' behaviors should be measured through the construction of a variety of variables on the possible social and natural determinants.

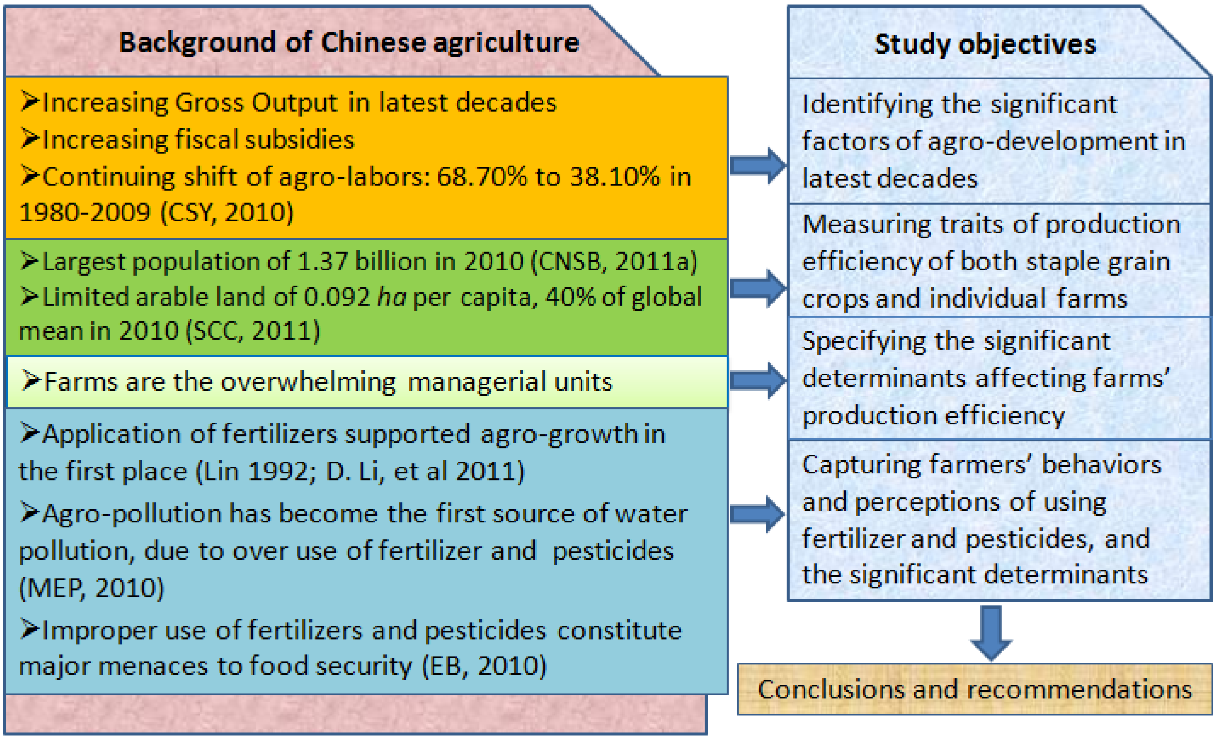

Fig.1-2 Background and objectives

1.2 Study objectives

According to the background analyzed above, the study aims to analyze the impacts of component factors in gross agricultural development, efficient production of major agro-products and individual farms, and identify countermeasures to improve agricultural productivity, with sufficient, safe supply of agro-products; rational, efficient and proper application of production factors, and sustainable, friendly effects to the environment.

Specifically, as shown in Fig.1-2, the main objectives include: (1) identifying the significant factors of agro-development in latest decades; (2) measuring the traits of production efficiency of both staple grain crops and individual farms; (3) specifying the significant determinants affecting farms' production efficiency; (4) capturing farmers' behaviors and perceptions of using fertilizer and pesticides, and the significant determinants. Based on the findings of these analyses, conclusions will be drawn, following by policy recommendations.

1.3 Organization of this thesis

Based on the study background and objectives outlined in Chapter 1, the remaining chapters are to be organized as follows (Fig.1-3).

Chapter 2 conducts a factor analysis of Chinese agricultural development after 1983, based on the time-series data issued by the government, and the main model is Cobb-Douglas production function. The application of chemical fertilizer is measured as the most important factor. As the second factor, technical progress promotes agricultural development in considerable degree, while the contribution rate from institutional transition is comparatively low. Finally, a variety of suggestions are made on the topics such as safe application of chemical fertilizer, popularization of agro-tech, the increase of agro-capital, reduction of agro-labor (D. Li, *et al* 2011b).

In Chapter 3, a framework on wheat production efficiency including 2 outputs and 7 inputs is developed, adopting an input-oriented DEA model with the assumption of VRS. The data source is the agricultural product survey, conducted by Price and Cost Inspection Bureau of Hebei in 2008, with 36 counties sampled as the Decision Making Units. From the outputs of DEAP 2.1, for most of these counties, production efficiency can still be improved through reducing some of the inputs, in addition to enlarging farm scales. Slack analysis of the outputs shows that comparing with technical improvement, much more margin lies in the socio-economic optimization. Meanwhile, slack analysis of inputs indicates that the inputs can be saved with 19 percent; fertilizer amount is the first constraint input, while machine rent is the least. Based on these findings, policy implications are put forward, concerning the circulation of land, strengthening the construction of public agricultural facilities, and deepening the institutional reforms to promote extension of agricultural technologies (D. Li, *et al* 2011a).

With the same database and DEA model, production efficiency of corn is measured in 44 counties of Hebei Province Chapter 4. Furthermore, production efficiency in corn and wheat are compared with Crosstabs Analysis. Finally, policy implications are put forward, concerning the adjustment of farming scales, marketing facilitation thus improve the added value, constructing the infrastructure and mechanization (D. Li, *et al* 2011c).

In Chapter 5, agricultural production efficiency from the perspective of individual farms, using another input-oriented DEA framework with 2 outputs and 6 inputs. The data source is a survey to 99 household farms of Hebei province, China, conducted by the authors in 2010. In the second stage, effects of a variety of social and natural determinants are assessed, with the adoption of an Ordinal Logistic Regression model. Based on the empirical findings, policy recommendations are put forward (D. Li, *et al* 2012a).

Chapter 6 studies farmers' application of fertilizers, based on a survey to 560 household farms in six provincial regions of eastern China. The main contends include total amounts, main components of chemical fertilizers and the use of organic fertilizers.

Then, it summarizes the farmers' perceptions, ranging from fertilizer choosing, field application, disposal of the used packages and awareness on the possible consequences of over fertilization. Nine indicators are adopted as the predictors, including information on the householders, land-using and planting structure, household income and geographical location. Fertilization Coefficient is formulated to isolate effects of farms' geographical location and planting structure, hence capture farmers' propensities on fertilizing. Through the adoption of binary logistic regression models, significant determinants are identified behind farmers' behaviors. Finally, policy recommendations are put forward, from increasing fertilization efficiency of both chemical and organic fertilizer, to improving farmers' capability and awareness of scientific fertilization (D. Li, *et al* 2012b).

Furthermore, based on the same survey, farmers' application of pesticides is studied in of Chapter 7. The contents include amounts of chemical pesticides, use of toxic pesticides and biological pest-control methods. Meanwhile, it summarizes the farmers' perceptions, ranging from pesticides choosing and field application to the awareness on the withdrawal period, possible consequences of overdosing and disposal of the containers. Through the adoption of multivariate OLS and logistic regression models, significant determinants affected farmers' behaviors are identified. Finally, several policy recommendations are put forward (D. Li, *et al* 2012c).

Finally, after summarizing the major conclusions of the foregoing chapters, Chapter 8 puts forward a variety of policy recommendations, in respect to improve the agricultural growth and production efficiency, while maintaining the proper behaviors and perceptions on the application of fertilizers and pesticides.

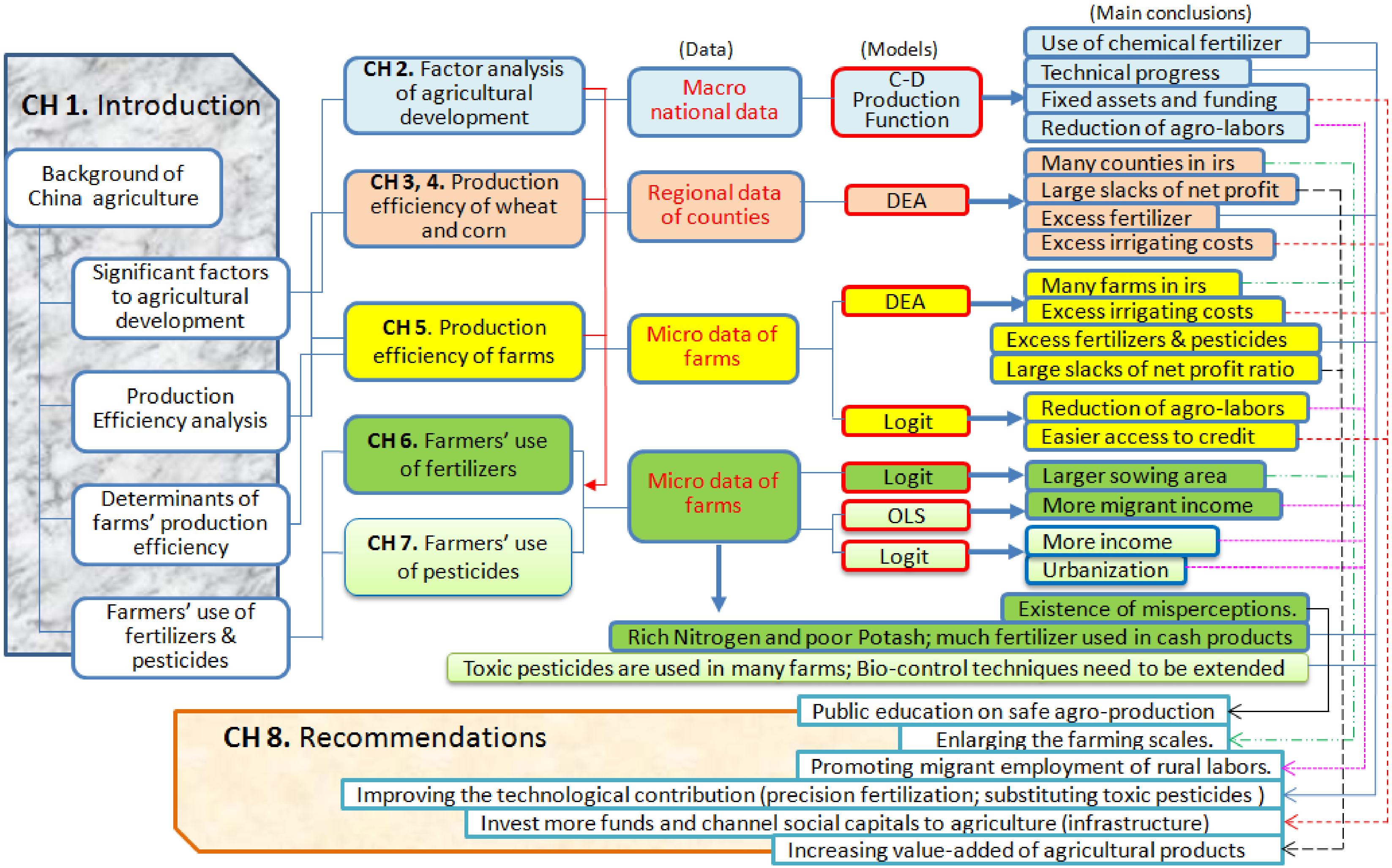

Fig.1-3 Flow chart of the whole dissertation

Chapter 2 Factor Analysis of Gross Agricultural Development

2.1 Introduction

In the end of 1978, China launched *Reforms and Opening-up*, thus broke up the highly-planned economic institutions, and revitalized the whole economy from rural areas. Until the mid-1980s, as a prelude of the *Reform and Opening-up*, the *Household Contract Responsibility System* has been expanded in nationwide rural areas, where production teams were dissolved within 99 percent of villages and major production materials, symbolized by farmland, were divided into household farms. After the reform, farmers can keep the rest as private properties, once paid a certain amount of food or agricultural tax to the state as contracted. It released the long-term bounded farming organizations, and increased farmers motivation on agricultural productivity, hence agricultural development reached a high level within a few years. As a fundamental measurement, total grain yields amounted to 379 million tons in 1985, from 305 million tons in 1978. With this growth rate of some 25%, the problem of food security, which puzzled China for a long time, was resolved by large. In addition to benefiting national life and industrial development, it brought new opportunities to the overall economic reforms. At the same time, thanks to the effects of non-agricultural reforms, agriculture gradually developed as an industry capable of self-reliance.

By the mid-1980s, the rapid development of agriculture is realized primarily due to the powerful potential released by institutional reforms. By contrast, in subsequent periods, agriculture maintained the high-speed growth, under the progress of overall economic reforms. From 1983 to 2006, China's Gross Agricultural Output (GAO) raised from 275 billion yuan to 4242.44 billion yuan (current prices). Accounting the influences of inflation, the GAO was 1242.70 billion yuan with constant prices of 1983, an average annual growth rate of some 6.88% was maintained in this period.

As shown below, factor analysis of China's agricultural development has been conducted by J. Y. Lin (1992), J. Wang (2009) and H. Zhang (2008), and other studies. However, these studies embrace problems as orienting on obsolete periods, focusing on specific factors of institutional factors, technological changes or changes in factor inputs. That is, it remains a challenge to the scholars of conducting comprehensive analyze and policy recommending on the reasons of agricultural development in recent periods, with the consideration of all the factors proposed above. Therefore, this chapter aims to clarify these issues, through factor analysis of China's agricultural development from the perspectives of inputs change, institutional transition and technological progress since 1983, when it began to develop as an independent industry by large. Within this macro analysis on the national time-series data, the approaches adopted are mainly production functions.

2.2 Development of Chinese agriculture and previous studies

In the study period, Chinese government esteemed rural areas as regions with great potentials to expand domestic demands, in addition to the conviction of fundamental position of agriculture in the rapid and stable economic growth. Therefore, in order to stabilize the *Household Contract Responsibility System*, further reforms are conducted on institutions of pricing the agricultural products, agricultural taxation, etc. In addition, to increase agricultural productivity and farmers' incomes, more funds are inputted to the development of agricultural sciences and technology, especially the innovation and extension of advanced agricultural production materials, new breeds. Thus, modernization of agriculture has been promoted, thanks to these agriculture-beneficial policies and technological advances. However, agriculture did not develop with continuous and fast speed, and significant differences existed between the annual growth rates. In particular, after a minus growth rate of 4.78 percent in 1989, an upheaval of 21.83 percent showed up in 1990 (Fig. 2-1).

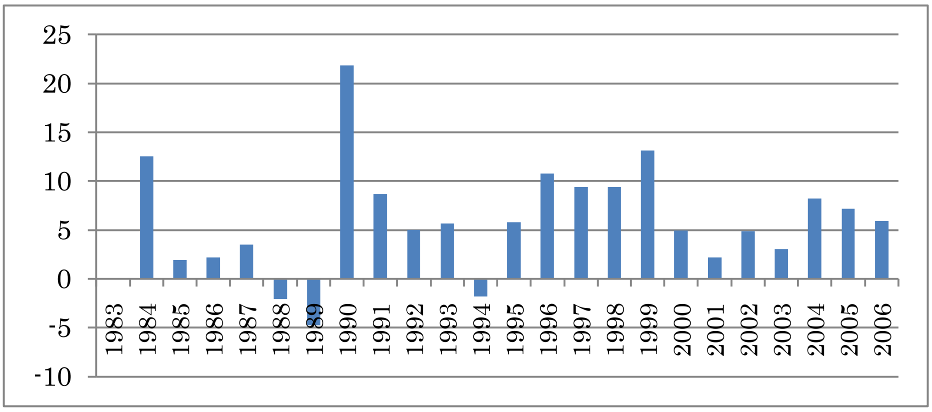

Fig.2-1 Annual growth rate of annual agricultural output in 1983-2006 (unit: %)

Source: Summary of Chinese Agricultural Statistics

On the lubricating growth of GAO mixed with untrimmed increases and even decreases, many scholars have explored the causes from different perspectives. J. Y. Lin (1992) analyzed the output elasticity of each factor in agricultural development from 1978 to 1984, used province-level panel data. According to the conclusion, as the most important factors in the first half period, rural economic institutional reforms from production teams to the *Household Contract Responsibility System* supported the increase of agricultural production with an important role of 19.80 percent. Meanwhile, significance of institutional reforms diminished sharply in the latter half of period. In succession, fertilizer application and technological progress (through the proxy variable of *T*) are measured as contributed greatly as well. To analyze significant factors behind development of Chinese agriculture, this study includes three factors of factor inputs, institutional changes and technological progress factor. However, as the study period is up to 1987, it necessary to conduct factor analyze of China's agricultural development within the following 20 years.

S. Huang *et al* (2005) conducted empirical analysis on the impact of Changes in land ownership system[1] to agricultural growth in 1949-1978, from the founding of People's Republic of China's to the *Reforms and Opening-up*. Conclusions of this study show the different effects of each factor to gross outputs of agriculture, in different stages of land ownership. This research has a long but demoded study period, and did not include the variable of technological progress. Aiming at understanding impacts of agricultural innovation system, Z. Qiao, *et al* (2006) analyzed the significant factors of Chinese agricultural development, in the five-divided period of 1978-2004, based on the model specified by Z. Griliches (1963). However, insignificant variables were included in some models for different periods such as *labor* and *power* in 1978-1984 and 1996-2002. Meanwhile, the study periods was divided into so many stages, especially included a two-year stage of 2003-2004, which reduced the accuracy of statistical analyses with models of multivariate regression, etc, thus blocked the accurate measurement of the whole study period from 1983 to 2006. In addition, this study did not include the contribution of technological progress.

Based on the panel data of provincial-level regions, H. Zhang *et al* (2008) analyzed the development of Chinese agriculture in 1949-2005. The result indicated that the physical inputs, particularly fertilizers and machinery, had a high contribution to the total agricultural output, farmland and labor contributed with lower or even negative ratios and large fluctuates. In this comprehensive empirical study, only the input elements were incorporated as determinants to agricultural development, while variables of technological progress and institutional change were excluded. In addition, Wang (2009) studied the relationship between technological progress and economic development in agriculture, with an extended Cobb-Douglas production function. It

[1] In the study period of this paper, land ownership in rural China passed through the stages of private ownership (1949-52), transition from private to collective ownership (1953-58), collective ownership through the people's commune (1959-62), and collective ownership of three subjects (people's commune, production brigade, production team), with the basis of production team (1963-78).

concluded that agricultural development increased the funds inputted on agricultural technical progress, while the latter needs to feed back the former mainly through the scientific conversion of concerning production elements and their organizations. Although this study oriented to a long period of 1986-2004, impacts of institutional change were not incorporated into the model (Table 2-1).

In previous studies, the development of Chinese agriculture was primarily attributed to three kinds of factors. The elemental inputs are the quantity of farmland, labor and agricultural assets, in addition to the liquid capitals of chemical fertilizers, etc. Institutional transitions refer to the changes of land ownership, agricultural price system, rural finance taxing forms, etc. Technology progresses include advances in farming methods related to increase production capacity of agricultural machinery and chemical fertilizers, and improved varieties of agricultural products. However, as noted above, there is still a blank topic of studying the period since 1983, when agriculture began to develop as an independent industry, with the adoption of the aforementioned factors to an integrated model, thus measure the respective impacts the development of Chinese agriculture. Meanwhile, further explorations are necessary in terms of the most appropriate indicators models to reflect impacts from the capitals, land or the other factors.

Therefore, with such awareness, based on data in 1983-2006 and production functions, after thoroughly examine the significance of each factor, this chapter selects a variety of indices with availability of credible data, to demonstrate the impact of agricultural development. In detail, taking the 24-year period as a whole [1], the introduced time series data covers all the three types of variables as summarized above, i.e., inputs changes, technological progress and institutional transitions.

[1] To illustrate the impact of institutional changes, the author introduced several dummy variables, and estimated the study period in different phases. However, the results did not show significant trend in terms of institutional changes, due to the short periods, thus statistical insignificance of each model.

Table 2-1 Estimation on the factors of China's agricultural development in previous studies

	Period	Factor and production elasticity													R^2
		Land	Labor	Capital	Agro-power	Fertilizer	Household contract	Multi-crop	Cash crops	Price ratio	Price reform	Tax & costs reform	Public financial aid	Agro-tech	
J. Y. Lin	1978-84	-0.74	1.91	4.57		13.60	19.80	-0.82	1.56	-0.32	6.75			12.60	
(1992)	1984-87	-1.61	-2.95	1.88		2.26	0	0.88	1.17	5.36	-5.04			6.30	
S. Huang,	1949-52	0.01	0.59		0.11	0.18					-0.25				0.850
et al	1953-58	0.50	0.42		-0.06	0.06					0.00				0.925
(2005)	1959-62	0.73	0.33		-0.09	0.04					0.28				0.913
	1963-78	0.34	0.40		0.03	0.09					0.24				0.816
	1978-84	-0.98	0.82		4.68	18.11	20.99			0.06					0.994
Z. Qiao,	1985-87	0.46	0.68		6.19	0.13				-0.52					0.998
et al	1989-95	-0.17	-0.84		5.88	2.05				-1.60		-0.56	11.80		0.998
(2006)	Feb-96	0.15	0.14		1.46	6.96				0.06		-0.15	0.33		0.994
	Apr-03	0.52	0.24		1.30	0.81				0.17		1.95	1.99		0.998
	1984-87	-0.65	0.38		0.97	0.44									0.995
H. Zhang,	1988-96	-1.54	0.94		2.86	0.23									0.917
et al (2008)	Mar-97	-0.30	0.27		0.22	0.23									0.996
	May-04	0.34	-0.49		1.05	0.64									0.994
J. Wang (2009)	Apr-86		0.45			0.47								0.34	0.990

Note: The Agro-power is the sum of the energy used in agriculture; price ratio is the ratio of price index of agricultural products and production materials; price reform is represented by ratio of product prices determined by the government; tax & cost reform is represented by the proportion of agricultural tax in total agricultural production; financial support refers to the proportion of fiscal inputs to agriculture in total public budgets

2.3 Methods and data

2.3.1 Theoretical model of production function

In studies about sources of economic development, Cobb-Douglas production functions[1] are widely used to demonstrate the relationships between economic growth and inputting factors. As the original theoretical model, Cobb-Douglas production function is represented by the following formula:

$$Y = \beta_0 e^{\theta t} \prod_{n=1}^{N} x_n^{\beta_n} \tag{2-1}$$

Here, x_n represents the inputting factors of capital, labor, etc, and β_n is the elasticity of each factor; β_0 includes all the other factors thus be called as Total Factor Productivity (TFP); t is a proxy variable for the time trend variable of technological progress; β_0, β_n and θ are unknown parameters to be estimated.

Taking the natural logarithm on both sides of Eq.2-1, and calculating the partial differential of ln$Y$ with t:

$$\frac{\partial \ln Y}{\partial t} = \theta \tag{2-2}$$

where θ represents the rate of technological progress (S. Sakano, *et al* 2004). Hence, the Cobb-Douglas specification of production function implicitly assumes the technological change effect is constant to the output Y (T. J. Coelli, *et al* 2005). Meanwhile, as the Cobb-Douglas specification of production function is homothetic, thus assuming that the substitute elasticity between different factors constant to be 1[2] (Y. Kuroda, 2005).

In theory, using the model described above, we can compute the contribution of technological progress over time. However, as the rate of technological change is not

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[1] In the studies of relationships between economic growth and inputting factors, in addition to production function, cost function and profit function are often used as well. Nevertheless, independent price variables are needed in both of the latter two functions. In addition, cross-sectional data were used in many prior studies on cost and profit functions (Y. Kuroda 2005). In China, only part of price data of production factors has been published. Therefore, this paper conducts factor analyze of Chinese agricultural development with the adoption of production function.

[2] Despite the single homogeneous assumption of substitutability between the elements, similar homogeneity (i.e., constant returns to scale) is not assumed for the returns to scale, which is determined by the parameters to be estimated. For example, if $\Sigma\beta_n$= 1 means constant returns to scale; $\Sigma\beta_n$<1 indicates the diminishing returns to scale; $\Sigma\beta_n$>1 denotes increasing returns to scale.

constant every year, there highly possible difficulties to observe the contribution over time. Therefore, another specification of production function is needed as:

$$Y = \beta_0 \prod_{n=1}^{N} x_n^{\beta_n} \tag{2-3}$$

Here, contribution of technological progress can be calculated with:

$$M_{Tech} = 1 - \sum_{n=1}^{N} M_n \tag{2-4}$$

That is, contribution of technological progress (M_{Tech}) is obtained as the residual of subtracting the contribution of other factors (M_n) from the growth rate of *Y* (K. Ogawa, *et al* 2002; S. Sakano, *et al* 2004). This thus provides another basic method to estimate the contribution of technological progress, based on the Cobb-Douglas production function (S. Inamoto, 1969). In this study, after compare results of the two models, the better performed Eq.2-4 is adopted.

2.3.2 Indicators and data

In this chapter, to describe the development of Chinese agriculture and the factors over the period, indicators shown in Table 2-2 are adopted. The data sources include *Bulletin of Chinese Agricultural Development* (2007), and *China Statistical Yearbook* (relevant years), published by China's Ministry of Agriculture and State Statistical Bureau. Considering the impacts of time trend, all the monetary values are calculated in the constant prices of 1983.

Table 2-2 Summary statistics of Chinese agricultural development in 1983-2006

Var.	Description	Unit	1983	2006	Annual growth (%)
Y	Gross Agricultural Output (GAO)	billion *yuan* [a]	275.00	1242.70	6.78
Ld	Sowing area of agricultural plants	million *ha*	143.99	157.02	0.38
Ats	Value of fixed agricultural assets	billion *yuan*	53.40	237.82	6.71
Pw	Power of agricultural machineries	million *kw*	180.22	726.36	6.25
Fert	Amounts of chemical fertilizer	million *ton*	16.60	48.34	4.76
Lb	Number of agricultural labors	10000 *person*	316.45	294.05	-0.32
Rp	Price indices ratio of agro-products and inputting materials	%	101.36	99.70	-0.07
Rt	Ratio of agricultural taxes in fiscal revenue	%	4.25	0.95	-6.31
Rf	Ratio of fiscal agro-aiding funds in GAO	%	4.83	7.48	1.92

Note: [a] As the prime currency unit, 7.97 yuan = 1 US$ (middle exchange rate of 2006), and all the monetary values are calculated in the constant prices of 1983

Source: Bulletin of Chinese Agricultural Development (2007); China Statistical Yearbook (relevant years)

In the first place, as the dependent variable, Gross Agricultural Output (*Y*) is the total output value of the final products of agricultural activities, including farming, forestry, animal husbandry and fishery. The gross output of each agricultural product (Y_t) is obtained by multiplying the price and physical volumes of production, and then converted to the constant prices of 1983.

Due to the existence of multiple cropping in agricultural production, Sowing area of agricultural (*Ld*), rather than the areas of arable land, is adopted (Z. Qiao, *et al* 2006). In origin, labor force (*Lb*) is should be represented with of total working days or hours in a year, etc. However, viewing from the real status of Chinese farmers, their laboring times are difficult to be accurately measured. Meanwhile, relevant data is not found from *China Statistical Yearbook*, *China Agricultural Yearbook*, and other sources. Therefore, referring to the earlier literature of J. Y. Lin (1992), Z. Qiao, *et al* (2006), etc, annual number of agricultural labors (10 thousand persons per year) is adopted in this study.

Agricultural capitals are divided into fixed and liquid capitals. The *value of fixed assets* (*Ats*) is the monetary expression of objects, tools and equipments directly used upon agricultural production, borrowed or owned by farms over a relatively long period of several years. Power Agricultural machineries (*Pw*) is the sum of energy with machineries used in ploughing, irrigation, harvesting and transportation, etc., within the agricultural activities of farming, forestry, animal husbandry and fishery. In order to identify appropriate variables to represent the fixed capitals, *Pw* and *Ats* are incorporated into the model simultaneously. At the same time, as the most important liquid capital, Amounts of chemical fertilizer (*Fert*) refers to the standardized quantity of Nitrogen, Phosphorus, Potash and compound fertilizers used in agricultural production. Here, the standardization depends on the content of nitrogen, phosphorus pentoxide, potassium, etc, in different types of fertilizers.

Meanwhile, three indicators are included to reflect the impact and effectiveness of institutional reforms in the study period, concerning agricultural commodity prices, agricultural taxation, aids and assistance to agricultural production, etc. Price indices ratio of agro-products and inputting materials (price ratio, *Rp*) is the ratio of price index and producer price indices for agricultural materials in each year. Series of reforms carried out in the field of agriculture, which began from institutions of commodity prices in early 1980s. Thereafter, the price system once generally controlled by the state being gradually reformed over a long period. By 2004, the fixed purchase prices are completely abolished and grain prices are began to be fully determined by the market. Meanwhile, Ratio of agricultural taxes (*Rt*) is the percentage of agricultural taxes in national fiscal revenues of each year. The agro-supporting funds are mainly used to finance agricultural production, irrigation, climate forecasting, infrastructure, R&D, etc.

Ratio of fiscal agro-supporting funds (*Rf*) refers to the percentage of public funds within Gross Agricultural Output (GAO). Using these two indicators, we intend to evaluate the impact from reforms of agricultural taxation and fiscal institutions. Since 2000, the rural tax reforms were included to the unified reforms managed by the central government. Until 2006, agricultural taxes were fully abolished in a nationwide scope, and subsidies supporting agricultural production began to be directly distributed to the farmers. At the same time, reform of the budgetary expenditure on agriculture finance came into force. In 2004, to balance the socio-economic development of urban and rural areas, the No.1 document issued by the top authorities proposed the key guideline of the rural policies as Giving More, Taking Less and Loosening Control, stressing that the government would increase its input to rural areas and agriculture, reduce taxes and fees collected from farmers. Meanwhile, another policy agenda was committed to transform the lack of financial input to agriculture[1] in the same document.

2.4 Results and discussion of the model

2.4.1 Results of the estimation

In this study, factors analysis of agricultural is conducted through the development of an econometric model without the inclusion of time variable, based on the log-linear Cobb-Douglas production function as:

$$\ln Y = \text{Constant} + \alpha \ln Ld + \beta_1 \ln Ats + \beta_2 \ln Pw + \beta_3 \ln Fert + \gamma \ln Lb + \delta_1 \ln Rp + \delta_2 \ln Rt + \delta_3 \ln Rf + \varepsilon \quad (2\text{-}5)$$

where *Constant* is the intercept, α, β_i, γ and δ_i are unknown parameters to be estimated, and ε is the random item.

Although we can include all the above variables into the final model and obtain higher fitness, it is better to develop models by omitting redundant variables which hardly contribute the total fitness. In econometric models, the change of determinant coefficient $\triangle R^2$, the change of F ($\triangle F$), and the probability significance of $p_{\triangle F}$ are referential in selecting the variables (Murase, *et al* 2007). After removing the insignificant variables according to the probability significance of $p_{\triangle F}$ obtained by the software SPSS, the combination of the explanatory variables in the final model include four significant variables as shown in Table 2-3.

[1] In terms of the financial inputs to agriculture, the total sum draws much more attentions than the proportion in annual government expenditure. In latest years, the fiscal inputs to support agriculture are increasing, while the proportion in annual government expenditure even decreased. In 1983-2006, the proportion decreased from 9.43% to 7.85% (China Statistical Yearbook).

Table 2-3 Estimation of the production elasticity

Variable	Constant	*Lb*	*Ats*	*Fert*	*Rf*
Elasticity	7.672**	-0.824**	0.159***	0.988***	0.306***
t	(2.436)	(-2.665)	(2.848)	(12.265)	(4.824)
Indicator	Sample size	*F*	Adj.R^2	*D-W*	
Value	24	586.085***	0.99	2.285	

Note: ***, **and *represent statistical significance in the level of 1%, 5% and 10% respectively

Software: SPSS 13.0

All the significant *F* and *t*-test in the level of 5 percent, the Adj.R^2 of 0.99, and Durbin-Watson value of 2.285 indicate good statistical fitness. In addition, fixed assets, chemical fertilizers, ratio of fiscal agro-supporting funds are all estimated as with positive elasticity. Although the negative elasticity of agricultural labor is adverse to the general economic assumption, it meets with existence of over surplus numbers of labors in Chinese agricultural production. In previous studies, both J. Y. Lin (1992) and Z. Qiao, *et al* (2006) have measured negative elasticity of labor productivity. Therefore, this model estimates well China's agricultural and economic growth in the study period.

To analyze the causes of significant ratio of fiscal agro-supporting funds, while insignificant pricing factors, it may due to lower prices of agricultural products compared with the prices of fertilizers and other inputting industrial products, thus farmers are difficult to be positive towards agricultural productivity. In terms of the sowing area of agricultural plants, insignificance may be resulted mainly from Multicollinearity, as high relation coefficients of 0.95 and 0.87 exist between this variable and value of fixed assets and fertilizer, respectively. Meanwhile, viewing from changes of inputs over the study period, when sowing area of agricultural plants increased 9.05 percent, value of fixed assets and amount of fertilizer increased 345.38 percent and 191.26 percent, respectively. In respect to the major crops, acreage of grains and cotton declined 7.50 percent and 11 percent respectively, thanks to the increased per unit yields of 38.88 percent and 63.45 percent, the total yields eventually increased by 28.45 percent and 45.48 percent, respectively. Similarly, total yields of oil crops increased by 189.99 percent, due to the increased per unit yields of 77.12 percent. To sum up, in the study period, comparing with the physical inputs of fertilizers and fixed assets, etc, hence the increased in yield per unit, sowing area exerted slightly smaller effects, thus of which the insignificant result in the quantitative model is plausible.

2.4.2 Contribution of each factor

In the study period, although the gross agricultural output increased by 351.89

percent, number of agricultural labors decreased by 7.08 percent, from 316 million to 294 million. In addition, the value of agricultural fixed assets increased from 53.4 billion yuan to 237.8 billion yuan, amounted more than four times; the three-fold increased of fertilizers were amounted from 16.60 million tons to 48.34 million tons. Ratio of fiscal agro-supporting funds in gross agricultural output rose from 4.83 percent to 7.48 percent as well. Based on the multiplication of these changes on each factor and the corresponding elasticity, the contribution rate of agricultural growth can be assessed for each factor using percentage within total agricultural output. Furthermore, as shown in Eq.2-4, contribution of agricultural technological progress can be estimated by subtracting the contributions of the other factors (Table 2-4). In addition, as investment on agricultural R&D is already included in financial support for agriculture, the technological progress in this context means the rest part by subtracting the investment on agricultural R & D from the government.

Table 2-4 Contribution of each factor (1983-2006)

		Y	*Lb*	*Ats*	*Fert*	*Rf*	*Tech* [a]
Total change (%)	(1)	351.89					
	(2)		-7.08	345.38	191.26	54.87	—
Elasticity	(3)		-0.82	0.16	0.99	0.31	—
Contribution (%)*	(3)×(2)/(1)		1.66	15.57	53.70	4.77	24.30

[a] Contribution of technological progress (*Tech*) is calculated based on Eq.2-4

Software: Excel 2007

According to the results of Table 2-4, within the growth rate of 351.89 percent of Gross Agricultural Production in the study period, the increased amount of fertilizers, value of fixed assets, amount of financial supports and the reduction of agricultural labor force, contributed with the share of 53.70 percent, 15.57 percent, 4.77 percent and 1.66 percent, respectively. Meanwhile, being the residual of the four variables, technological progress contributed 24.30 percent to Chinese agriculture development. Among the factors, increase in the amount of fertilizer inputs is the most major factor, following by technological progress. These two factors accounted for 78 percent of gross agricultural output growth, constituting major causes of Chinese agricultural development over the study period.

In succession, value of fixed assets processes great increases but small elasticity, thus the contribution remained to be 15.57 percent. As a proxy of institutional changes, Ratio of fiscal agro-supporting funds in GAO shares a small contribution of 4.77 percent in the study period. In terms of the minus and small elasticity of agro-labor, a share of

1.66 percent is contributed due to the decreased numbers over the study period.

These results are in lines with conclusions of the prior studies. Firstly, as the basic agricultural production materials, the detected significant effects of chemical fertilizers is similar with J. Y. Lin (1992), Z. Qiao, *et al* (2006), Zhang, *et al* (2008) and many other studies. As key factor in the second place, the importance of technological progress is measured in Wang (2009) and other prior literature. As to the negative elasticity of agro-labor number, which is in line with J. Y. Lin (1992) and Z. Qiao, *et al* (2006), it indicates that transferring of agro-labor numbers have contributed to Chinese agricultural development. The major reasons behind include engaging in other sectors enables the farmers to obtain more funds investing on fertilizers and fixed agricultural assets. Meanwhile, the non-agricultural experiences are beneficial in improving farm management and trade of agro-products.

2.5 Conclusions and recommendations

2.5.1 Major conclusions

In this chapter, a factor analysis of Chinese agriculture development in 1983-2006 is conducted, from the perspectives of inputs change, institutional transition and technological progress. As a result, new findings did not show up in similar studies were obtained, through comprehensive perspectives, overall and long-term modeling and comparison of different models in measuring the contribution of technological advances, etc.

From the statistical significance of each factor, with increment of chemical fertilizer in the first place, fixed agricultural assets, followed by financial supports and the reduction of agricultural labor force constitute the major factors supported China's agricultural development in the study period. In previous literature, different factors were detected as the first factor in different stages, such as agricultural technology in J. Y. Lin (1992), agricultural machinery and financial assistance in Z. Qiao, *et al* (2006), agricultural machinery and labor force in Zhang (2008), etc (Table 2-1). In contrast, increased input of fertilizer is measured as the most important factor for China's agricultural development in 1983-2006, with an overwhelming contribution share. In addition, as the second factor, technological progress is concluded as supported agricultural development with a considerable share of contribution. Different from the models in Z. Qiao, *et al* (2006) and Zhang (2008), Wang (2009) considered the significance of agricultural technology, although measure as contributed with the lowest share among three types of factors. Inaccurate measurement of the contribution of agricultural technological progress will inevitably mislead the understanding of the significant factors and thus policies recommendations of agricultural development. Finally, although J. Y. Lin (1992) and Z. Qiao, *et al* (2006) have suggested that institutional changes is a key factor for China's agricultural growth since the middle of 1980s, this study shows that compared with the other factors, institutional changes holds a relatively low contribution share. It suggests that since the mid-1980s, despite the series policies in favor of agriculture, few fundamental institutional changes like household contracting system is carried out, or that the institutions are not implemented effectively.

2.5.2 Major recommendations

Based on the above conclusions, the following policy recommendations can be raised to accelerate agricultural development. First, the increased input of chemical fertilizers has contributed significantly and the amount is expected to keep increasing in future. Nevertheless, the realization of sustainable and environmentally friendly agriculture has become an important issue. Therefore, for the safe application of chemical fertilizers, the government needs to extend soil surveying techniques, and promote the proper classification and appropriate amounts of fertilizers. Thereby, increase agricultural productivity while savings fertilizer costs and protecting the environment.

Meanwhile, as another important factor, advances in agricultural technology should be accelerated three perspectives of R&D, extension and funds. At present, although agricultural technology has developed rapidly in China, problems still remain in transferring and spreading the techniques to the fields. To analyze the causes, the overwhelming ratio of household management, thus the small sizes of farmland in agriculture can be attributed. The individual farms are limited in willingness and ability to introduce new agricultural technologies. In the governmental institutions specializing in extending agricultural technologies, irrespective connection of staffs' incomes and their achievements in extending agricultural technology, thus lack of initiatives can be pointed out as another reason. Thus, in addition to enlarging the managerial scales though encouraging the transfer of farmland use rights, marketing reforms upon the extending institutions of agricultural technology, especially from the grassroots, constitutes an urgent measure simultaneously.

At the same time, there are countermeasures needed to serve agricultural labors, number of which is estimated with a significant but minus production elasticity above. To reduce the number of agricultural labors, further endeavors are necessary to strengthen the non-agricultural vocational training of rural labors by the *Sunshine Project*[1], accelerating the reform of the family registration system, so as to shift surplus

[1] *Sunlight Project* is a series of technical and vocational training programs to the rural labors, carried out by the Chinese government since 2004. The Project aims to improve quality and skills of rural labors, thus

labors to both the urban areas and local non-agricultural sectors.

In addition, as an important factor of institutional change, fiscal agro-supporting funds needs to be increased. Despite the relative low capital elasticity, the increase of fiscal agro-supporting funds is highly beneficial to increase the value of fixed assets and the promotion of agricultural technology advances. Thus, to deepen the reforms of the financial budget on agriculture and transform the lack of fiscal inputs on agricultural, it necessary to ensure sources of funds channeled to agriculture, from a series of sources including governmental departments and financial institutions. Specifically, the main roles of government include the investment on agricultural infrastructure construction, subsidies on the purchase of agricultural machinery and good seeds. Meanwhile, financial institutions are expected to create preferential prerequisites to provide more loans to farmers.

2.5.3 Open research topics

In recent years, with China's rapid economic development, agricultural inputs are being increased, and the extension of agricultural technology is being enhanced. In addition, the overall abolition of agricultural taxes, and direct aid to agricultural production, etc, a series of Agro-supporting policies was carried out by 2006. Therefore, although this study could not fully grasp impact of these policies, further studies are necessary to assess China's overall agricultural growth factors, using annual data since 2007.

promote their employment in rural non-agricultural sectors and urban areas.

Chapter 3 Wheat Production Efficiency in 36 Counties of Hebei Province

3.1 Introduction

As a province surrounding Beijing (Fig.3-1), Hebei is one of the 13 main grain-growing provincial regions[1] in China, with wheat the most important grain in this province. In 2008, Hebei accounted for 10.87 percent of the national aggregate outputs and 10.23 percent in sown areas of wheat. Both of the two indicators ranked the 3rd, and the average output *per hectare* was 5.06 *ton*, ranked the 6th amongst all the 31 provincial regions. Judging from the three indicators, wheat is relatively advanced in ranking than the other staple grains in Hebei[2]. Therefore, efficient production of wheat is of great importance not only to this province but also the whole country.

To evaluate and promote agricultural production efficiency, the research perspectives can be divided into two categories. In some cases, including Meng, *et al*. (2004), Hu, *et al*. (2006) and C. Daniel, *et al*. (2010), different regions were esteemed as *Decision Making Units* (DMUs) being analyzed and compared. Meanwhile, many of the other researches took their DMUs to the individual farms, like Chen, *et al*. (2009), D. Bhima, *et al*. (2010), etc. In either of the two categories, indicators and data that compatible with characteristics of the objects were indispensible. Been the third level of Chinese local administrative hierarchy after provincial and prefectural regimes, county is the final level having complete government divisions and economic industries. In the regulation of agriculture, the central and provincial governments identify the developing states and allocate funds to aid agriculture in units of counties. Due to different fiscal and natural conditions, amount of subsidies for seeds, fertilizer and agro-machines are differing amongst counties. Therefore, this chapter intends to study wheat production efficiency from the perspective of county-level regions in Hebei province.

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[1] The 13 major gains-growing provincial-level regions include Liaoning, Jilin, Heilongjiang, Inner Mongolia, Hebei, Henan, Hubei, Hunan, Shandong, Jiangsu, Anhui, Jiangxi and Sichuan.

[2] In terms of total output in Hebei, rice and corn ranked the 24th and 5th, while from the perspective of total sown areas, they were placed the 23th and 4th respectively. Both of the grains were ranked 16th according to the average yield per hectare.

Fig. 3-1 Location of Hebei Province

Source: http://gochina.about.com/od/maps/ig/Province-Maps/Hebei-Province-Map.htm

Since the pioneering work of M. J. Farrell (1957), a considerable literature has devoted to the estimation of efficiency. Generally, they can be categorized into two approaches: the parametric function symbolized by Stochastic Frontier Production (SFP) (D. Aigner, *et al*., 1977), and the nonparametric Data Envelopment Analysis (DEA) (A. Charnes, *et al*., 1978). Both methods estimate the efficiency frontier, which it is considered as the best performance observed among the firms, and calculate the other firms' relative efficiency. The main strength of the SFP is that it deals with stochastic noise and permits statistical tests of hypotheses pertaining to production structure and degree of inefficiency. Meanwhile, the requirement of a specified frontier production function is the main weakness of this approach. In contrast, using linear programming to construct a piece-wise frontier that envelops observations of all firms, the DEA embraces the advantage that multiple inputs and output can be considered simultaneously, and they can even be quantified in different units of measurement. Moreover, this approach avoids the parametric specification of technology as well as the distributional assumption for the inefficiency terms, and it does not claim the weights on different inputs and outputs as well (T. J. Coelli, 2005).

In agricultural production, many resources, including land, labor, fertilizer, etc, are being used, thus needs multiple-input models to measure the efficiency. As to the outputs, a variety of variables can be adopted to measure not only the physical yield but also the market value. Both the input and output variables are in different units, without any parameters can be assumed accurately beforehand. Therefore, we will conduct a wheat-growing efficiency analysis using an input-oriented DEA model with the assumption of VRS[1]. As in many instances, the choice of orientation has only a minor influence upon the efficiency scores to be obtained. Essentially, one should select the orientation according to which quantities (inputs or outputs) the managers have most control over (T. j. Coelli, 2005). For most of the famers, what they can control relatively free would be the quantity of inputs, rather than the outputs, to agricultural production. Meanwhile, natural and marketing risks, government regulations, constraints on finance, etc., may cause a farm cannot operate at optimal scale.

To identify the effects of concerning social and natural factors, a two-stage DEA model is in wide application. To model the DEA scores and relevant determinants in the second stage, there are three major approaches being used, including *Tobit* regression, the Papke-Wooldridge (PW) model and the unit-inflated beta (Beta) model. However, as proved by H. Ayoe (2007), *Tobit* regression performs better that the other two and many literature have adopted it to identify the factors significant to agricultural production efficiency as A. Martine, *et al*. (2003), I. J. Mohammad, *et al*. (2008), D. Bhima, *et al*. (2010), etc.

Although county-level areas are essential in the study of Chinese agricultural productive efficiency, few researches have aimed at this kind of regions with the adoption of two-stage DEA model like C. Daniel (2010). Therefore, we intend to fulfill the following targets in this chapter: 1) formulating a DEA model appropriate to analyze wheat production efficiencies taking Chinese counties as the DMUs, 2) revealing the overall attributes of wheat production efficiencies, 3) finding out the theoretical margin for the increasing of yields and abbreviation of the inputs in wheat production, 4) identifying the significant social and natural factors that affecting the wheat production through the application of *Tobit* regression, and 5) putting forward referential countermeasures for policy makers as well.

3.2 Theoretical framework of DEA

3.2.1 Basic model

DEA includes a variety of linear programming procedures, in which a non-parametric frontier is constructed over the data, and efficiencies of the DMUs are measured relative to this surface (T. J. Coelli, *et al* 2005). A. Charnes, *et al* (1978) proposed

[1] There are two orientations in DEA model, the input-oriented model seeks to reduce in inputs, with outputs hold constant, while the output-oriented model aims to increase outputs, with inputs keep fixed. As to the assumption of return to scale, Constant Return to Scale (CRS) is appropriate when all firms are operating at an optimal scale, while Variable Return to Scale (VRS) without this limitation.

an input-oriented model with the assumption of CRS, based on which R. D. Banker, *et al* (1984) included the situations of VRS by adding the constraint of I1′λ=1:

$$\begin{aligned} & \underset{\theta_i,\lambda_i}{Min}\,\theta_i \\ st.\quad & -y_i + Y\lambda_i \geq 0, \\ & \theta_i x_i - X\lambda_i \geq 0, \\ & \mathrm{I1}'\lambda_i = 1, \\ & \lambda_i \geq 0,\quad 0 \leq \theta_i \leq 1 \end{aligned} \qquad (i=1, 2, \ldots, n) \qquad (3\text{-}1)$$

where Y and X are the output and input matrix, y_i and x_i are the output and input for the i-th firm, respectively. λ_i is an n×1 vector, serving as a weight system to each firm and thus form a optimal combination of inputs and outputs (the frontier); θ_i is a scalar for each firm, indicating the extent of x_i been used to catch up the optimal combination of inputs, and a value of 1 indicates a point on the frontier hence a technically efficient DMU. I1 is an n×1 vector of 1, ensuring that sum of all the weights assigned to the benchmarking firms equal to 1, thus the fabricated benchmarks (the optimal combination of inputs and outputs) are similar in scale with the i-th firm (T. J. Coelli, *et al* 2005). Therefore, the DEA model of Eq.3-1 seeks to reduce inputs as much as possible, relative to the empirically constructed identical and optimal combination of inputs and outputs for each firm (P. Maria, *et al* 2010).

If the θ_i obtained from the CRS DEA differs from that out of VRS DEA, it indicates the existence of scale inefficiency (T. J. Coelli, *et al* 2005). Thus the θ_i obtained from the CRS DEA (the total efficiency or economic efficiency) is decomposed into two components, one due to the scale inefficiency and one due to pure technical inefficiency (*i.e.* VRS TE).

3.2.2 Nature of returns to scale

The nature of returns to scale can be determined by running an additional procedure with Non-increasing Returns to Scale (NIRS), which can be imposed through substituting I1′λ=1 with I1′λ≤1 in Eq.3-1. The nature of the scale inefficiencies for a firm can be determined by comparing the NIRS TE with the VRS TE. If they are unequal, then Increasing Returns to Scale (*irs*) exists; if they are equal, then Decreasing Returns to Scale (*drs*) apply; if in a firm where $TE_{CRS} = TE_{VRS}$, *i.e.*., SE=1, then the firm is operating under Constant Returns to Scale (*crs*) (T. J. Coelli, *et al* 2005).

3.2.3 Radial and slacks adjustment

Radial and Slacks Adjustment are illustrated in Fig.3-2, where efficient firms (the frontier) are assumed using input combinations of C and D. Meanwhile, A and B are inefficient firms, with the efficiencies measured as *0A'/0A* and *0B'/0B*, respectively. The distance from an inefficient point, like *A*, to the projected point on the frontier, like *A'*, is called Radial Adjustment (T. J. Coelli, *et al* 2005). In some cases, Slack Adjustment occurs due to the piece-wise linearity of the non-parametric frontier and finite sample sizes. In Fig.3-2, because the section *CS* of the linear frontier is parallel to the vertical axe, the amount of input x_2 can be reduced by *CA'* while producing the same output, thus making *A'* not a most efficient point for firm *A*. The amount of *CA'* is known as Slack Adjustment or Input Excess in the literature (J. Hu, *et al* 2006). Therefore, for firm *A*, the total adjustment for input x_2 includes two parts: Radial Adjustment (*A'A*) and Slack Adjustment (*CA'*).

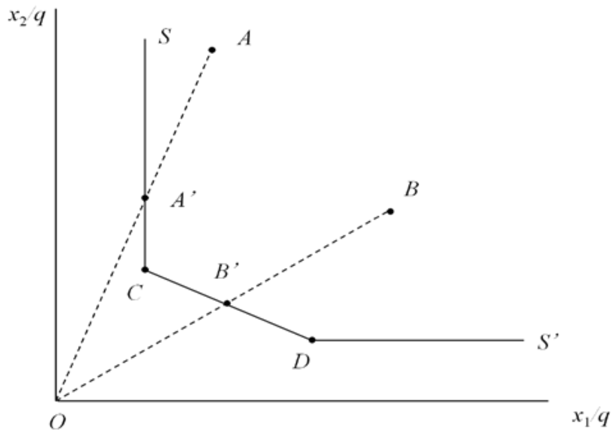

Fig. 3-2 Efficiency measurement and input slacks

Source: (T. J. Coelli, *et al* 2005)

Similarly, in the output-oriented Fig.3-3, the efficiency of an inefficient firms *P* can be measured as *0P/0P'*, while output q_2 can be increased by *P'A* as the output slack with the same input, thus making *P'* not most efficient for firm *P*. The total adjustment for output q_2 is divided into two parts: Radial Adjustment (*PP'*) and Slack Adjustment (*P'A*).

Generally, radial and slack adjustment show the inefficient and redundant amounts of inputs respectively, and their summation is the gap between the original and target quantity of each input. In this study, we extend the notion of radial and slack adjustment, i.e., allocate inefficiency (T. J. Coelli, *et al* 2005), into the models with multiple inputs and outputs, and conduct analyses amongst individual farms.

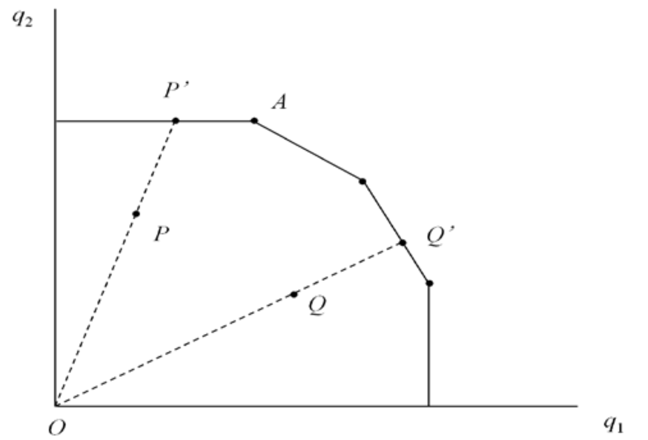

Fig. 3-3 Efficiency measurement and output slacks

Source: (T. J. Coelli, *et al* 2005)

3.3 Model and data

3.3.1 Literature review

The review of literature fielding in two-stage DEA models on agricultural efficiency will benefit the modeling of wheat production efficiency. From models in the selected five former researches shown in Table 3-1, we can get a profile about the general trend of relevant literature.

Firstly, as to the selection of *outputs*, although DEA models are open for multiple adoptions of indicators, only P. C. Jean, *et al*. (2005) and C. Daniel, *et al*. (2010) shown in dual or multiple variables. Moreover, except for I. J. Mohammad, *et al*. (2008), most of the outputs were in physical forms and the corresponding monetary value was not reflected. Secondly, in formulating the *inputs*, it is rather unified that they covered most of the physical input for farming, including labor, land, fertilizer, seeds, pesticide, tractor services, etc. Finally, mainly three categories of variables were used as social and natural determinants, the characteristics of family members like *age of farm leader*, *years of schooling*; farm productive conditions like *distance to market*, *financial market access*; and the socio-economic variables like *composite of GDP, labor and population*. Dummy variables occurred in some cases like the health condition and ethnic affiliation in A. Martine, *et al*. (2003).

C. Daniel, *et al*. (2010) included more socio-economic variables, because it took Chinese counties as DMUs. By contrast, the other farm-based researches were inclined to adopt farm variables as the determinants. In addition, according to S. Grosskopf (1996), in order to avoid an inconsistent and biased second-stage estimates, the explanatory variables used in the second stage should be uncorrelated with the variables used in the production function. A. Martine, *et al*. (2003) checked this form with the correlation matrix between the inputs and the determinants, while all the other researches were in lack of this procedure.

Table 3-1 Models of agricultural efficiency in several former researches

	A. Martine 2003	P. C. Jean 2005	I. J. M. 2008	D. Bhima 2010	C. Daniel 2010
Output	Physical output of cotton	Physical output of vegetable, fruit, etc	Total farm income	Physical output of vegetable	Physical output of grain and meat
Input	Value of equipment, sown area, number of labors, geographic location	Labor, sown land, cost of fertilizer, pesticide, tractor service and seeds	Land, tractor, seed, pesticide, labor, irrigation hours	Land, labor, oxen, fertilizer, seeds, pesticide, irrigation	Labor, mechanical power, fertilizer, sown area
Determinant	Percentage of literate adults, age of family head, health condition, ethnic affiliation, sowing data, family and social cohesiveness	Gender, migrating of the family head; ratio of adults female, children; financial market access; land fragmentation and tenure security	Farm size, years of schooling, age of farm leader, contact with extension agents, farm to market distance, access to credit	Age of farm leader, schooling years, family size, year of farming, land area, income per capita, credit access, training	Structure of agriculture including GDP share, intensity of mechanical power, GDP per capita; credit and fiscal relatives to GDP and expenditure; industrial ratio, labor and population composition,

3.3.2 Defining the variables

Considering the practice of agricultural production among Chinese household farms, mechanisms of DEA, the model consists of 2 outputs, 7 inputs and 8 determinants to measure the efficiency of wheat production (Table 3-2).

Output variables

For most of the farms, agricultural products including wheat, corn, etc, are not only indispensible food material, but also important source of income. Observing from a macroscopic view, efficient production of agricultural products is vital for food self-sufficient and poses a foundation for the national economy as well. For these reasons, two variables are included as outputs: *yields of main product* refers to net weight of raw wheat in standard moisture content[1], and it implicates the physical productivity of wheat, thus the capability of fulfilling the food demand and guarantee food safety in each county. *Net profit* is the balance of the gross profit minus costs on all the inputs in wheat farming. The costs consist of (1) inputted material and service, including seeds, fertilizer, pesticides, and hired machinery for irrigation, plough, sowing, etc.; (2) labor costs consisting values of hired labors and converted value of family labors; (3) land costs consisting value of rented lands and converted value of family-owned farming land allocated by the Household Contract Responsibility System. Generally, this variable can reveals the profitability of wheat farming, under a variety of curtain technical, marketing and political institutions. Therefore, the greatest difference between the two output variables is that the former is a technical indicator, while the latter is a socio-economic one.

Table 3-2 Variables and the summary statistics of wheat production efficiency

Variable		Description of the variable	Unit	Max	Min	Mean	Std. D
Output	y_1	Yields of main Product	*kg/mu* [a]	508.9	308.3	417.84	45.94
	y_2	Net profit	*yuan/mu*	319.25	6.21	160.08	81.29
Input	x_1	Farming time	*day/mu*	8.74	2.77	5.67	1.37
	x_2	Land rent	*yuan/mu*	141.67	60	101.87	22.76
	x_3	Seeds	*kg/mu*	27.33	10.83	17.21	4.01
	x_4	Fertilizer	*kg/mu*	39.44	21.13	28.11	4.30
	x_5	Machine rent	*yuan/mu*	115.5	64.44	91.88	12.31
	x_6	Irrigation cost	*yuan/mu*	83.15	14.26	45.25	16.28

Note: [a] as a main unit of land measurement in China, 1 *mu*=666.67m^2.

Data source: Inputs and outputs from Agricultural Product Survey 2008, Price and Cost Inspection Bureau of Hebei; determinants from the concerning departments of Hebei

Input variables

(1) *Labor inputted* is the standard days of labor needed by wheat farming. To calculate this variable, the farming time of both family members and hired labors should be standardized referring to a moderate labor[2], and then divided by 8 hours. (2) *Land inputted* is monetary value of land inputted as a productive element, including real rent

[1] Standard moisture content is the percentage of water and varies in different regions. In most of the cases, it is around 12-13 percent in Hebei province.

[2] Moderate labors include: 1) 18-50 year old male and 18-45 year old female, able to adapt moderate labor intensity. 2) labors out of the age interval stipulated above, but can undertake equivalent labor intensity. and 3) the employed labors.

of land circulated from individuals or the collectives, and theoretical rent of own-farming land allocated by the Household Contract Responsibility System. (3) Physical amount of seeds used in wheat farming, including the bought, self-produced and donated for free, form the variable of *Seeds inputted* here. (4) Similarly, *Fertilizer inputted* is the amount of fertilizer used in wheat farming, which has been standardized according to its contents of active principles[1]. (5) *Machine service rent* is the expenditure for the mechanical operation including plough, sowing, harvest, threshing and transportation. (6) *Water inputted* includes the expenditure for the rent of irrigating equipments, and the costs occurred in irrigating.

3.3.3 Sample and data

The data of inputs and outputs used in this chapter are got from the agricultural product survey, conducted by Price and Cost Inspection Bureau of Hebei in 2008. In addition, we got some data from the Hebei Statistical Yearbook 2009, and the Bureau of Statistics, Department of agriculture and Department of water resources in this province, for a complete database of the determinants.

As a branch of the national survey of China, the survey covered the staple agricultural products, including wheat, corn, cotton, pork, egg, and the characteristic agricultural products like pear, date, apple, etc. The survey was conducted throughout almost 1000 farms, distributing in 76 counties of all the 11 prefectures in *Hebei*. All the sampled farms were paid for keeping regular records of the inputs and outputs in the farming of each product. In the database of the agricultural price and cost provided by Price and Cost Inspection Bureau, wheat production was sampled in 36 counties of 8 prefectures, and the concerning summary statistics of each input and output variables in 2008 are listed in Table 3-1.

3.4 Efficiency analysis with DEA

3.4.1 Total, technical and scale efficiencies

Efficiency Summary in Table 3-3 shows that amongst the 36 counties, 10 counties are scored in Total efficiency as 1, thus in the status of full efficiency and stand for benchmarks for the other inefficient counties. For convenience of analysis, the 10 counties are defined as *Type* I in this chapter. Furthermore, within the rest 26 counties with Total efficiency less than 1, there are 8 counties, referred as *Type* II, bearing a pure

[1] For example, 50 kg of diammonium phosphate containing 18 percent of nitrogen and 46 percent of phosphorus pentoxide will be standardized as 32 kg (50kg×18%+50kg×46%). The chelate fertilizers and bacterial manure need not be standardized.

technical efficiency score equals to 1. It indicates that in these counties, adjustment of any input will not change the output efficiency, and it makes enlarging the farm scales the only solution to improve production efficiency. Meanwhile, there are still 18 counties, referred as Type III, having a technical efficiency scoring less than 1. It means that in these counties, with given farm scale, production efficiency can still be improved through reducing some of the inputs. In fact, it is an important objective and function of DEA model to identify and calculate quantity of inputs reduction for this kind of firms, as to be shown for the 18 Type III counties later in this chapter.

As the analysis above, all the 10 counties in Type I are being constant returns to scale, while all the 8 counties in Type II are in the status of increasing returns to scale. In Type III, 16 counties are being increasing returns to scale, and two counties are in the status of decreasing returns to scale. Therefore, in altogether 24 counties, efficiencies can be improved by enlarging the farm scales, and 2 by contraction.

Table 3-3 Summary of wheat production efficiency

Type	Number of counties	Means			Number of counties with		
		Total efficiency	Technical efficiency	Scale efficiency	*crs*	*irs*	*drs*
I	10	1.000	1.000	1.000	10	0	0
II	8	0.889	1.000	0.889	0	8	0
III	18	0.835	0.900	0.927	0	16	2
Total	36	0.902	0.959	0.940	10	24	2

Note: *crs* = constant returns to scale; *irs* = increasing returns to scale; *drs* = decreasing returns to scale

Software: DEAP 2.1

3.4.2 Slack analysis of the outputs

Slack of an output shows the margin that firm can improve the output through the adjustment by DEA. The output slacks summarized in Table 3-3 shown that only the *Type* III counties, outputs can be increased through the adjustment according to the DEAP 2.1. In this group, yields of main product can be increased by 3.75%, from 417.93 *kg* to 433.60 *kg per mu*. Meanwhile, the net profit *per mu* of wheat can be increased to 242.66 *yuan* by 110.70 *yuan*, which accounts for 83.88 percent of slack adjustment in counties of this group. Calculating in the total 36 counties, farms can increase their average net marginal profit of 34.57 percent, which is much larger than the 1.87 percent of average physical yields of wheat. It indicates that comparing with technical improvement, much more margin lies in the socio-economic optimization including marketing regulation, integration of agro-aiding funds, etc., so as to improve the profitability of wheat-farm.

Table 3-4 Slack analysis of outputs

Type	Number of count	Mean of main product (*kg*)			Mean of net profit (*yuan*)		
		Origin1	Target1	Slack1	Origin2	Target2	Slack2
I	10	458.83	458.83	0.00	245.67	245.67	0.00
II	8	366.38	366.38	0.00	116.36	116.36	0.00
III	18	417.93	433.60	15.66	131.97	242.66	110.70
% of slack	Type III	100.00	103.75	3.75	100.00	183.88	83.88
	Total	100.00	101.87	1.87	100.00	134.57	34.57

Software: DEAP 2.1

3.4.3 Radial and slack analysis of the inputs

The DEAP 2.1 can give the Radial and Slack movement for each county. As mentioned above, for the counties of Type I and II, the pure technical efficiencies equal to 1 and there is no margin to adjust the input with the same level of output. Therefore, radial and slack analysis is conducted only in the 18 counties of *Type* III (Table 3-5).

Table 3-5 Radial and slack analysis on inputs per *mu*

	Input					
	Farming time (*day*)	Land rent (*yuan*)	Seeds (*kg*)	Fertilizer (*kg*)	Machine rent (*yuan*)	Irrigation cost (*yuan*)
Origin	5.80	108.43	17.30	28.94	93.91	50.82
Slack	-0.14	-4.16	-0.61	-0.32	-4.99	-11.63
% of slack	-2.49	-3.83	-3.55	-1.10	-5.31	-22.88

Software: DEAP 2.1

As implicated by (A. Martine, *et al*., 2003), the slacks provide an indication of the inputs that are in excess supply. Within Type III, water fees can be decreased with the largest margin of 22.88 percent, following by machine rent with 5.31 percent, showing the relatively redundant and inefficient usage of the two kinds of inputs. Meanwhile, the input amount of fertilizer is shown the efficient usage with the margin of only 1.10 percent. The rank of each variable in terms of their constraining capacity indicated by the slack margin and number of counties have thus be proved the same, and it will be beneficial to increase the production efficiency of wheat through adjusting the supply of inputs.

3.5 Concluding remarks

This chapter measures the production efficiency of wheat production in Hebei Province, China, through the adoption of DEA model. It reveals that amongst the 36 sampled counties, 11 counties are in the status of constant Returns to scale, and 2 counties are displayed the state of decreasing returns to scale, while the rest 23 counties are demonstrating the trend of increasing returns to scale. Therefore, in most of the counties, enlarging the scale of wheat farming will improve the relative production efficiency. Meanwhile, within the 23 counties, there are still 14 counties have a technical efficiency scoring less than 1, which means that with the given farm scale, production efficiency can still be improved through reducing some of the inputs.

The yields of main products *per mu* can be increased by 1.28 percent, while the net profit *per mu* of can be increased by 27.20 percent. All the 7 inputs can be saved 19 percent, amongst which Machine rent can be decreased with the largest margin, following by water fees, showing the relatively redundant and inefficient usage of the two kinds of input. Meanwhile, the input amount of fertilizer is shown the efficient usage with the lowest margin.

In the next chapter, the same analysis framework will be applied on the production efficiency of corn, another staple grain crop in Hebei Province; comparison study will be conducted between wheat and corn in some counties; policy recommendations will be put forward to improve production efficiency of the two staple grain crops.

Chapter 4 Corn Production Efficiency in 44 Counties of Hebei Province

4.1 Introduction

In addition to wheat, corn is another staple grain crop in China, growing from Heilongjiang in the northeast to Hainan in the south. Since the 1980s, with the economic development, although direct food demands have decreased, corn is increasingly needed in forage and food processing industries. As one of the 13 main grain-growing provinces in China, Hebei accounts for 8.69 percent of yields and 9.51 percent of sown areas in China's corn production of 2008, ranked the 5^{th} and 4^{th} respectively. However, the average output was 338.41 kg per mu, less than the national mean of 370.38 kg per mu and ranked 17^{th} amongst 31 provincial regions (China Statistical Yearbook, 2009). As J. Meng, (2010) concluded, Hebei is advantageous in the scale of corn production, but disadvantageous in technical efficiency.

As introduced in the former chapter, the literature measuring agricultural production efficiency can be divided into two categories. L. Meng, *et al* (2004), Hu, *et al* (2006) and C. Daniel, *et al* (2010), took different regions as the *Decision Making Units* (DMUs), while many other researchers set their DMUs to individual farms, including Zhuo, *et al* (2009), D. Bhima, *et al* (2010), etc. In the five-level hierarchy of Chinese administrative system, county is the lowest level having complete government divisions and economic industries. Moreover, the government identifies the state of agricultural development and allocates funds in units of counties. Therefore, this study intends to measure corn production efficiency from the DMUs of different counties in Hebei province, China.

In this chapter, we intend to fulfill the following targets: 1) formulating a DEA model appropriate to analyze corn production efficiency taking Chinese counties as the DMUs, 2) revealing the overall attributes of corn production efficiency, 3) finding out the theoretical margin for the increasing of each output and saving of inputs in the sampled counties of Hebei Province, 4) and putting forward policy recommendations.

4.2 Variables and data specification

4.2.1 Defining the variables

Considering the realities of agricultural production in the sampled counties, combining the mechanism of DEA and referring to the previous researches, the study intends to specify a model consisting of 2 outputs and 6 inputs, to measure the corn production efficiency (Table 4-1).

Output variables For most of the farmers, agricultural products including corn, wheat, etc, are not only indispensible food material, but also important source of income. Observing from a macroscopic view, efficient production of agricultural products is vital for food self-sufficient and poses a foundation for the national economy as well. For these reasons, two variables are included as outputs: *Yields of main product* refers to the net weight of raw corn in standard moisture content[1]. This variable implicates the physical productivity, hence the capability of fulfilling the corn demand and guarantee food safety in each county. *Net profit* is the balance of the gross profit minus costs of all the inputs revealing the profitability of corn production, determined by a variety of technical, marketing and political institutions. Therefore, the greatest difference between the two output variables is that the former is a technical indicator, while the latter is a socio-economic one.

Table 4-1 Variables and the summary statistics of corn production efficiency

Variable		Description of the variable	Unit	Max	Min	Mean	Std. D	C.V.
Output	y_1	Yields of main Product	*kg/mu*[a]	546.30	349.40	468.73	55.71	0.12
	y_2	Net profit	*yuan/mu*	412.15	16.76	179.95	89.44	0.50
Input	x_1	Farming time	*day/mu*	10.11	3.50	6.48	1.49	0.23
	x_2	Land rent	*yuan/mu*	141.67	46.67	100.70	22.08	0.22
	x_3	Seeds	*kg/mu*	3.61	2.34	2.82	0.26	0.09
	x_4	Fertilizer	*kg/mu*	31.30	9.74	17.42	5.04	0.29
	x_5	Machine rent	*yuan/mu*	85.56	17.44	54.61	18.88	0.35
	x_6	Irrigation cost	*yuan/mu*	55.89	0.00	18.79	13.10	0.70

Note: [a] as a main unit of land measurement in China, 1 *mu*=666.67m^2.

Data source: agricultural product survey 2008, Price and Cost Inspection Bureau of Hebei

Input variables (1) *Farming time* is the standard days of laboring needed by corn production. To calculate this variable, the farming time of both family members and hired labors should be standardized referring to a moderate labor[2], and then divided by

[1] Standard moisture content is the percentage of water and varies in different regions. In most of the cases, it is around 12-13 percent in Hebei province.

[2] Moderate labors including: 1) 18-50 year old male and 18-45 year old female, able to adapt moderate labor intensity. 2) labors out of the age interval stipulated above, but can undertake

8 hours. (2) *Land rent* is monetary value of land inputted as a productive element, including real rent of land circulated from individuals or the collectives, and theoretical rent of farmland allocated by the Household Contract Responsibility System. (3) Physical amount of seeds used in corn production, including the bought, self-produced and donated for free, form the variable of *Seeds* here. (4) Similarly, *Fertilizer* is the amount of fertilizer used in corn production, which has been standardized according to the contents of active principles[1]. (5) *Machine rent* is the expenditure for the mechanical operation including plough, sowing, harvest, threshing and transportation. (6) *Irrigation cost* includes the expenditure for the rent of irrigating equipments, and the costs occurred in irrigating.

4.2.2 Sample and data

The data of inputs and outputs used in this study are gathered from the agricultural product survey, conducted by *Price and Cost Inspection Bureau* of Hebei in 2008. Details of this survey have been introduced in Chapter 3. In terms of the efficiency analysis of corn production, 44 counties of all the 11 prefectures of Hebei Province are sampled and the summary statistics are listed in Table 4-1.

4.3 Efficiency analysis with DEA

4.3.1 Total, technical and scale efficiency

The efficiency summary provided by DEAP 2.1 shows that, amongst the 44 counties, 22 counties are scored 1 in Total, Technical and Scale efficiency, thus being deemed as in the status of full efficiency and can be stand for benchmarks for the other inefficient counties. For convenience of analysis, the 22 counties are defined as Type I in this study. Furthermore, within the rest 22 counties with Total efficiency less than 1, 7 counties, referred as Type II, bear Technical efficiency equals to 1. It indicates that in these counties, adjustment of any input will not change the output efficiency, thus adjusting the managerial scales is the only solution to improve production efficiency. Meanwhile, there are still 15 counties, referred as Type III, have technical efficiencies scoring less than 1 (Table 4-2). It means that in these counties, with given managerial scale, production efficiency can still be improved through reducing some of the inputs. In fact, it is an important objective and function of DEA model to identify and calculate quantity of inputs reduction for this kind of firms, as to be shown for the Type III counties.

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equivalent labor intensity. and 3) the employed labors.

[1] For example, 50 kg of diammonium phosphate containing 18 percent of nitrogen and 46 percent of phosphorus pentoxide will be standardized as 32 kg (50kg×18%+50kg×46%). The chelate fertilizers and bacterial manure need not be standardized.

Table 4-2 Summary of corn production efficiency

Type	Number of counties	Means			Number of counties with		
		Total efficiency	Technical efficiency	Scale efficiency	*crs*	*irs*	*drs*
I	22	1.000	1.000	1.000	22	0	0
II	7	0.942	1.000	0.942	0	5	2
III	15	0.846	0.938	0.903	0	15	0
Total	44	0.938	0.979	0.959	22	20	2

Note: *crs* = constant returns to scale; *irs* = increasing returns to scale; *drs* = decreasing returns to scale

Software: DEAP 2.1

As the theoretical analysis above, all the 22 counties in Type I are in the status of constant returns to scale, while in Type II, 5 counties are in the status of increasing returns to scale and 2 counties are in the status of decreasing returns to scale. In Type III, all the 15 counties are being increasing returns to scale. Therefore, efficiencies of corn production can be improved by enlarging the managerial scales in 20 counties, while in 2 counties by contraction.

4.3.2 Slack and radial analysis

Slack of output shows the margin that a firm can increase the output through the adjustment proposed by DEA. In this study, only in the *Type* III counties, outputs can be increased through the adjustment according to the results of DEA. The slacks summarized in Table 4-3 show that in this group, yields of main product *per mu* can be increased by 1.93 per cent, with the average slack of 26.59 *kg*. Meanwhile, the net profit *per mu* can be increased by83.80 *yuan*, and the slack adjustments account for 15.88 percent in the origin values. It indicates that comparing with technical improvement symbolized by total yield, much more margin lies in the socio-economic factors symbolized by net profit. Judging from the number of counties with output slacks, 14 counties can be improved in net profit, while 11 counties can increase their yields based on the results of DEA. Thus, the deepening of concerning institutional and political reforms, including the optimization of marketing regulation, integration of agro-aiding funds, etc., is important for the improvement of corn production efficiency.

In DEA models, slacks and radial movements show the *redundant* and *inefficient* amounts of inputs, respectively (T. J. Coelli, *et al* 2005). Meanwhile, as illustrated by A. Martine, *et al* (2003), since slacks indicate the inputs that are in excess supply, number of DMUs (here refer to the counties) shows the constraining capacity of each variable to the production efficiency, and the smaller the higher. As mentioned above, for the counties fall into *Type* I and II, the technical efficiencies equal to 1 and there will be no margin to adjust the input with the same level of output. Therefore, slack analysis is conducted only in the 15 counties of *Type* III. Table 4-3 shows that, *machine rent* is supplied with most *redundant* amount of 7.13 percent; *farming time* is the most constraining input, with only 0.26 percent in excess supplies[1] (Fig.4-1).

Similar relative constraining capacity of the inputs can be obtained through counting the number of counties with slack in each variable, as shown in the bottom of Table 4-3.

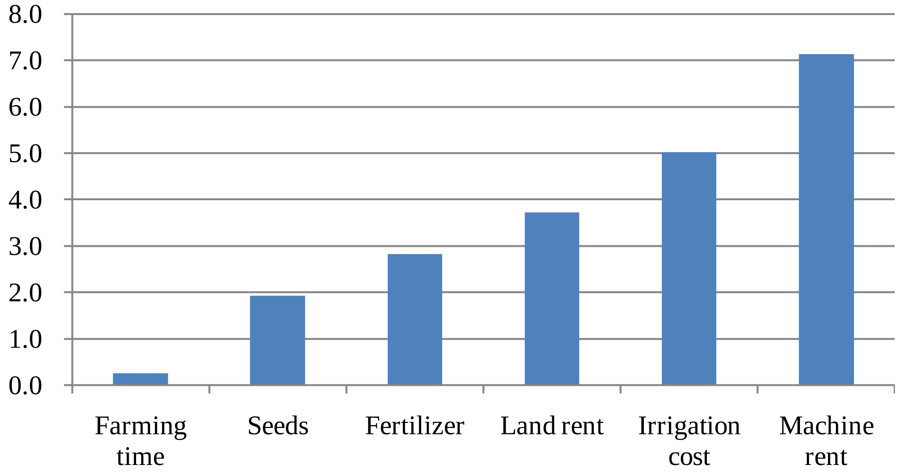

Fig. 4-1 Percentage of input slack

The movements of radial show that amongst the 6 inputs, there is no significant difference in the ratio of radical adjustments, and each input can be saved about 6-7 percent comparing with the benchmarking counties, for each county measured as inefficient in Type III. Amongst the 6 inputs, irrigation cost is most inefficient with the largest radial amount of 7.02 percent to be reduced, while the fertilizer can be saved with the least average ratio of 6.04 percent (Fig.4-2). It indicates the efficient application of fertilizer is of great importance for agriculture, as similar with the findings in prior study of the authors (Li, *et al* 2011).

[1] As demonstrated in many researches including the prior study of the authors (Li, *et al* 2011a), agricultural labor is in excess supply, and the reduction of which will improve the development of agriculture in China.

Table 4-3 Slack and radial movements per *mu* in counties of Type III

	Output		Input					
	Yield (*kg*)	Profit (*yuan*)	Farming time (*day*)	Land rent (*yuan*)	Seeds (*kg*)	Fertilizer (*kg*)	Machine rent (*yuan*)	Irrigation cost (*yuan*)
Mean of original value	447.71	127.20	6.78	103.44	2.86	17.80	58.73	20.72
Mean of slack	26.59	83.80	-0.02	-3.86	-0.06	-0.50	-4.19	-1.04
Mean of radial	0.00	0.00	-0.42	-6.63	-0.18	-1.08	-3.81	-1.45
Mean of target value	474.29	211.00	6.34	92.96	2.62	16.22	50.73	18.23
Percentage of slack (%)	1.93	15.88	-0.26	-3.73	-1.92	-2.82	-7.13	-5.02
Percentage of radial (%)	0.00	0.00	-6.23	-6.41	-6.38	-6.04	-6.49	-7.02
Number of counties with slack	11	14	2	3	3	2	5	4

Software: DEAP 2.1

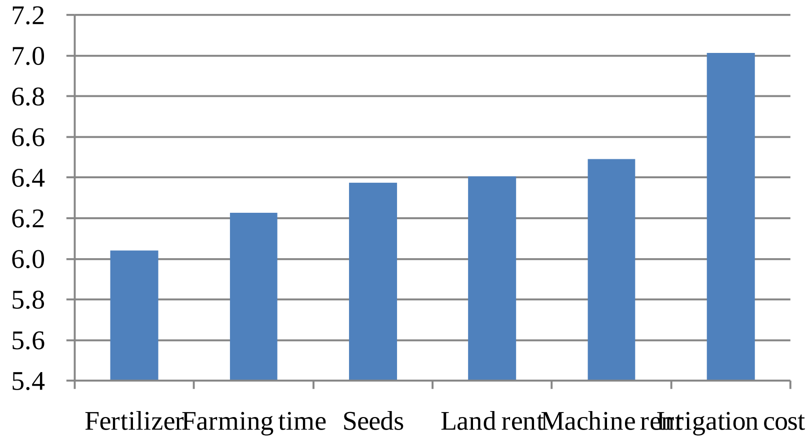

Fig. 4-2 Percentage of input radial

4.3.3 Comparison of efficient and inefficient counties

Based on the technical efficiency scores (Tech) provided by DEA, we can compare and obtain the general traits of the output and input variables in efficient (Tech=1) and inefficient (Tech<1) counties, thus verify the results of slack and radial analysis above and generate new findings. As shown in Table 4-4, both the physical and monetary outputs in the efficient counties are larger than those in the inefficient counties. Especially, the net profits differ 62.92 percent between the two kinds of counties, which is much larger than the gap of yield of main product as 7.13 percent. Fortunately, as demonstrated above, through the theoretical adjustments proposed by DEA, the monetary profit can be increased with a margin larger than that of the physical yields in the 15 technically inefficient counties.

Table 4-4 Comparison of efficient and inefficient counties

	Output		Input					
	Yield (*kg*)	Net profit (*yuan*)	Irrigation cost (*yuan*)	Machine rent (*yuan*)	Farming time (*day*)	Land rent (*yuan*)	Fertilizer (*kg*)	Seeds (*kg*)
(1) Tech=1	479.61	207.23	17.79	52.47	6.32	99.28	17.23	2.80
(2) Tech<1	447.71	127.20	20.72	58.73	6.78	103.44	17.80	2.86
(3)=(1)/(2) (%)	107.13	162.92	85.85	89.34	93.16	95.98	96.79	97.95

Software: Excel 2007

Nevertheless, all the efficient counties used less input than the inefficient ones. The ratios in the bottom of Table 4-4 show the percentages of inputs in the efficient and inefficient counties, the smaller of which means the more redundant and inefficient supply of the corresponding input, and *vice versa*. Similar with the results in slack and radial analysis, the irrigation cost is indicated as the most redundant and inefficient input, while the smallest differences are existing with fertilizer and seeds.

4.4 Comparison of production efficiency between corn and wheat

Based on the same survey by the Price and Cost Inspection Bureau of Hebei Province, we have measured the production efficiency of wheat (Li, *et al* 2010), another most important grain crop in Hebei[1]. The survey gathered data on both corn and wheat in 32 counties. Using DEA models in these counties can provide greater insights into the production efficiency of grain crops in this province, hence further countermeasures can be drawn as well.

Table 4-5 Crosstabs Analysis between corn and wheat production

Model [a]	Variables and counts of counties [b]				Tests of 2-sided significance
Tc×Tw		Inefficient Tw	Efficient Tw	Total	
	Inefficient Tc	7 (4.5)	2 (4.5)	9	Pearson $\chi^2(1)$=3.865
	Efficient Tc	9 (11.5)	14 (11.5)	23	Asymp. Sig. of Pearson χ^2 =0.049
	Total	16	16	32	Sig. of Fisher's exact test=0.113
Sc×Sw**		*crs* Sw	*irs* Sw	Total	
	crs Sc	9 (5.6)	9 (12.4)	18	Pearson $\chi^2(1)$=6.732
	irs Sc	1 (4.4)	13 (9.6)	14	Asymp. Sig. of Pearson χ^2=0.009
	Total	10	22	32	Sig of Fisher's exact test=0.019
Tc×Sc***		*crs* Sc	*irs* Sc	Total	
	Inefficient Tc	0 (5.1)	9 (3.9)	9	Pearson $\chi^2(1)$=16.099
	Efficient Tc	18 (12.9)	5 (10.1)	23	Asymp. Sig. of Pearson χ^2=0.000
	Total	18	14	32	Sig of Fisher's exact test=0.000
Tw×Sw***		*crs* Sw	*irs* Sw	Total	
	Inefficient Tw	0 (5)	16 (11)	16	Pearson $\chi^2(1)$= 14.545
	Efficient Tw	10 (5)	6 (11)	16	Asymp. Sig. of Pearson χ^2=0.000
	Total	10	22	32	Sig of Fisher's exact test=0.000

Note: [a] Tc and Tw represent the technical efficiency of corn and wheat, while Sc and Sw means the status of returns to scale of corn and wheat, respectively; *** and ** denote statistical significance in the level of 1% and 5% respectively. [b] numerals in the ( ) are the expected counts.

Software: SPSS 13.0

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[1] In 2008, the sown areas and aggregate yields of wheat in Hebei accounts for 10.23 and 10.87 percent in China, and both of the two indices ranked the 3rd in 31 provincial regions.

Crosstabs Analysis is an interdependence technique to explore the relationships of two numeric or categorical variables, in which the entries are the frequencies of responses that fall into each cell of contingency tables in matrix formats (J. F. Hair, *et al* 2010). Through the application of SPSS 13.0, Crosstabs Analysis identifies the relationships between technical efficiency and status of returns to scale in corn and wheat production as shown in Table 4-5.

In Crosstabs analysis, the Chi-square test assumes that the expected value for each cell is 5 or higher, but the Fisher's exact test has no such assumption and can be used regardless of how small the expected frequency is (J. Bruin, 2006). As except for the last model, the assumption of Chi-square test cannot be met, the Fisher's exact tests are used to measure the significance of relationships among different type of counties in this study.

According to the Fisher's exact tests, statistically significant relationship does not exist between Tc and Tw, while it does exist between Sc and Sw. The insignificant relationships between technical efficiency of corn and wheat may be resulted from the fact that, wheat is the most important food crop in Hebei, thus is inputted more than that of the corn, which is serving as forage crop in most of the cases[1]. At the same time, because corn and wheat are usually multiple cropped on the same plot of land in Hebei province (M. Han, 2006), the significant relationships of status on returns to scales with the two crops appeared in the 32 counties. Meanwhile, due to the laws of crop growth and yields within either of the two crops, significant relationships are demonstrated between technical efficiency and status of returns to scale. Farming scales should be increased in all the 9 inefficient counties of corn and the 16 inefficient counties of wheat production. In the efficient counties of both corn and wheat production, most of them are in the status of constant returns to scale.

In addition, judging from the counts of counties and the average scores of technical and scale efficiency of each county[2], we can conclude that in the 32 counties, corn is more efficient than wheat production; as the main way to improve production efficiency, increasing the farming scales is more important to the wheat.

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[1] In this survey of the 32 counties, the average inputs of fertilizer, mechanical rent and irrigation on each mu of corn were 17.12 *kg*, 57.01 *yuan* and 19.98 *yuan*, while the corresponding inputs on wheat were 28.22 *kg*, 91.87 *yuan* and 45.36 *yuan*, respectively.

[2] According to the results of DEA, the average scores of technical and scale efficiency with corn are 0.981 and 0.958, while the corresponding scores with wheat are 0.949 and 0.936, respectively.

4.5 Conclusions and recommendations

4.5.1 Main conclusions

Through the adoption of models DEA, this study measures the efficiency of corn production in 44 counties of Hebei Province, China. According to the efficiency scores provided by DEA, the 44 sampled counties are divided into 3 types. In *Type* I, the 22 counties are fully efficient and in the status of constant returns to scale, thus forming benchmarks for the other inefficient counties. In the 7 counties of *Type* II, due to the technical scores fixed to one, adjustment of any input will not change the output efficiency, thus production efficiency can only be improved through expanding the managerial scales in 5 counties, while the other 2 counties should compress their scales. Meanwhile, in the rest 15 counties of *Type* III, production efficiency can be improved through either reducing some of the inputs or compressing the managerial scales.

The output slacks analysis shows that, comparing with physical yields, net profit can be increased with a larger margin. The similar conclusions are drawn from the comparison of outputs in the efficient and inefficient counties. It indicates that comparing with technical improvement symbolized by total yield, much more margin lies in the socio-economic factors symbolized by net profit. In general, the liquid inputs including seeds, fertilizer and farming time are similar in the efficient and inefficient counties, with less slack and radial movements. Meanwhile, larger differences, slack and radial movements exist amongst inputs connecting with the construction of agricultural infrastructure, including the irrigation costs and machinery rents.

The crosstabs analysis of production efficiency in corn and wheat in 32 counties indicates that, statistically significant relationship does not exist between Technical efficiency, while it does exist between the returns to scale cross the two crops. However, significant relationship between the two types of variables within either of corn and wheat. Further comparison shows that corn is more efficient than wheat production; as the main way to improve production efficiency, increasing the farming scales is more important for wheat production.

4.5.2 Policy recommendations

According to the analysis above, corn production is more efficient than wheat in the sampled counties of Hebei Province. Therefore, steadily accelerating the corn production is of great significance to agriculture and concerning industries of Hebei Province. Because in most of the counties, enlarging the managerial scales will improve the relative production efficiency, a variety of policies should be strengthened to accelerate the enlargement of corn production. In the first place, circulation of farmland should be further encouraged, as larger farm scale can generate more penitential for efficient farming modes. In China, land performs as self insurance of subsistence for a long period. The government should encourage the concentration of land on farms' own willing, through favorite subsidies, financial and technological aids (J. Meng, *et al* 2010). Moreover, since the farmers cooperatives are developing quickly in latest year, especially after the execution of the Law on Specialized Farmers' Cooperatives in 2007, the cooperatives should be guided and encouraged to support corn production, including the purchase of capital goods, product marketing, credit accessing, etc. In some regions, Corn Farmers' Cooperatives can be founded through the support of government.

Facilitating the marketing of corn products, thus improve the value added and net profits of corn production. As reviewed by L. Gu (2010), the accelerated development of food processing and livestock industries is vital to corn production. The direct associations between corn farmers and enterprises should be reinforced, thus shortening the marketing chain and corresponding costs. Moreover, the byproducts of corn, including the straw, cob, etc, should be exploited through the development of relevant industries (Q. Yang, 2008).

Accelerating the construction of irrigating infrastructure and the process of agricultural mechanization, hence decrease the cost of irrigation and machinery operations. In the first place, as described in the No.1 Document of the Central committee of CCP[1], take full advantages from the special funds for the construction of water resources, accelerating the renovation of irrigating facilities and extension of water-saving facilities. Meanwhile, extend the efficient application of machine for the corn production, especially for harvest, through subsidizing the purchasers and research agencies. The financial institutions should be encouraged to support the corn machinery buyers, with lower interest rates, simpler loaning conditions and procedures, etc.

[1] As one of the most important documents from the central committee of CCP, the No. 1 document of 2011 was issued on Jan., 29th, outlined the perspectives and policies on the management of water resources. In the document, financial source was provided as in addition to the regular sources to be doubled within the next 10 years, 10 percent of revenue from land transactions will be reserved and used exclusively for the construction of water facilities.

Chapter 5 Agricultural Production Efficiency of 99 Household Farms from Hebei Province

5.1 Introduction

Being the largest developing country, China needs sufficient and safe supply of agricultural products, due to the increasing population, diminishing arable land and limited irrigating water (P. Chen, *et al* 2008). Moreover, efficient agricultural production constitutes foundation for the supply of sufficient food stuff and transfer of rural labors, thus supporting the development of national economy. Therefore, Chinese agricultural productivity has become a popular topic amongst researchers over the latest years (M. John, *et al* 1989; B. Hu., *et al* 2005; P. Chen, *et al* 2008, Z. Chen, *et al* 2009, C. Daniel C. M., *et al* 2010).

Since the pioneering work of M. J. Farrell (1957), many studies have devoted to estimate production efficiency. As introduced in the last two chapters, they are categorized into two approaches: the parametric functions symbolized by Stochastic Frontier Production (SFP, D. Aigner, *et al* 1977), and the nonparametric Data Envelopment Analysis (DEA, A. Charnes, *et al* 1978). Both methods estimate the efficiency frontier, which it is considered as the best performance observed among the firms, and being referred to calculate the other firms' relative efficiency. The main strengths of the SFP are that it deals with stochastic noise and permits statistical tests of hypotheses, pertaining to production structure and degree of inefficiency. Meanwhile, the requirement of a specified frontier production function constrains its applicability. By contrast, using linear programming to construct a piece-wise frontier that envelops observations of all firms, DEA embraces the advantages that being capable of bearing multiple inputs and outputs in different units of measurement. Moreover, DEA avoids the parametric specification of technology and the distributional assumption for the inefficiency terms, and it does not claim the weights on different inputs and outputs as well (T. J. Coelli, *et al* 2005).

A brief literature review on production efficiency measurement of Chinese agricultural shows that, there are still topics need to be researched with further depth. (1) As agricultural development is heavily influenced by external environment, it is necessary to assess not only production efficiency, but also effects of the social and natural factors. Although some papers, such as C. Daniel, *et al* (2010), conducted two-stage analyses, much more studies targeted only on measurement of Chinese agricultural efficiency, without modeling the effects of natural and social determinants in the second stage. (2) Because household farm is the basic and overwhelming managerial unit of Chinese agriculture, much more researches based on farm surveys should be conducted, to capture information from the micro-level perspectives (S. Tan, *et al* 2010). According to C. J. Carter, *et al* (2003), estimates derived by aggregate and individual data may lead to different conclusions and policy implications. However, many of the previous studies are based on second-hand aggregate datasets, especially the statistics of provincial regions. Z. Chen, *et al* (2009) evaluated technology and technical efficiency of Chinese farms, based on the farms survey conducted by China Ministry of Agriculture over 1995-1999, with the whole country being grouped in four regions. H. Dong, *et al* (2010) measured the agricultural efficiency of the 31 Chinese provincial-level regions in 2008. (3) Some studies focused on the measurement of production efficiency of one certain agricultural product (Y. Lu, *et al* 2009; Y. Liu, *et al* (2010), leaving many open research topics upon the overall efficiency evaluation of all the crops grown within individual farms. (4) Within DEA model, attributes of inputs, outputs and efficiency sores should be explored, both in different grouped farms and aggregate analysis of total farms, rather than describe the general characteristics as put in most of the previous studies.

Therefore, we intend to fulfill the following targets in this chapter: (1) formulating a DEA model appropriate to analyze agricultural production efficiency, taking Chinese household farms as the DMUs, (2) revealing the overall attributes of agricultural production efficiencies in each type of farms, (3) finding out theoretical margins for the increasing of outputs and saving of inputs, (4) identifying the significant social and natural factors that affecting the agricultural production efficiency, through the application of ordinal logistic regression, and (5) putting forward policy recommendations in the last section.

5.2 Variables and data specification

5.2.1 Data and software

This study is conducted based on data obtained from the farm survey conducted by the authors in August to October, 2010 (Appendix I). In this survey, 120 household farms from 48 counties of all the 11 prefectures of Hebei province are interviewed or answered our questionnaire. However, considering the integrity and rationality, responses from 99 farms are used in the study, with a valid ratio of 82.5 percent. Major agricultural products among the sampled farms include staple grain crops of wheat and corn; cash crops of cotton, millet, broomcorn, peanut, soybean, potatoes; and vegetables of cucumber, pepper, lettuce, carrot, etc.

Summary statistics of each variable are listed in Table 5-1.Through the software of DEAP 2.1, we solved the input-oriented DEA model with the assumption of VRS, the linear programming problems derived from Eq.3-1.

5.2.2 Defining the variables

Considering the reality of agricultural production in China, combining with the mechanism of DEA and indications from previous studies, the model specified in this study consists of 2 outputs, 6 inputs and 12 determinants, to measure agricultural production efficiency of the sampled farms (Table 5-1).

Output variables For most of the farms, agricultural production is not only indispensible source of food material, but also important source of income. *Net profit* refers to the balance of the gross revenue minus all the costs from annual agricultural production; *Ratio of net profit* is the percentage of net profits in the total revenue. The gross revenue is defined as sum of all the yields of agricultural products multiplied by the average prices, which are gathered from farms' selling experiences over 12 months until the survey. The costs include the monetary inputs of fertilizer, pesticide, land rent, seeds, machinery rent, irrigation cost, and labor rent.

Input variables (1) Farming time is shown in standardized days. To calculate this variable, farming time of both family members and hired labors are standardized referring to a moderate labor[1], and then divided by 8 hours. (2) Seeds include monetary values of the bought, self-produced and donated seeds. (3) Fertilizer and (4) Pesticides are the amounts of fertilizer and pesticides, respectively. (5) Machine service rent is the expenditure for mechanical operations including ploughing, sowing, harvesting, threshing and transportation. (6) Irrigation costs consist of the expenditure for the rent of irrigating equipments, and other costs occur during irrigation.

Determinants of efficiency The production efficiency of a firm is usually affected by a variety of social and natural determinants, including the natural conditions, change of policies, planting customs, etc. In the measurement of farm productivity, the funds, labor, and stuff including fertilizers and pesticides inputted to production should be included as input variable, while indicators on demographic information and farming conditions can be adopted as candidate determinants.

[1] The moderate labors include: 18-50 year old male and 18-45 year old female, who are able to adapt moderate labor intensity; labors out of the age interval stipulated above, but can undertake equivalent labor intensity; the employed labors.

Table 5-1 Variables and the summary statistics of agricultural production efficiency

Variable		Description of the variable	Unit	Max	Min	Mean	Std. D	C.V.
Output	y_1	Net profit per *mu* [a] (profit)	*yuan*/*mu*	2424.75	364.53	1117.57	381.03	0.34
	y_2	Ratio of net profit (ratio)	%	84.34	40.48	68.42	8.27	0.12
Input	x_1	Farming time inputted (time)	*day*/*mu*	17.00	1.00	3.74	2.22	0.59
	x_2	Seeds inputted (seeds)	*yuan*/*mu*	280.00	25.00	104.77	63.46	0.61
	x_3	Fertilizer inputted (fert)	*kg*/*mu*	170.00	26.25	65.08	26.97	0.41
	x_4	Pesticides inputted (pesti)	*kg*/*mu*	2.80	0.00	0.78	0.53	0.68
	x_5	Machine service rent (machr)	*yuan*/*mu*	150.00	0.00	62.84	37.73	0.60
	x_6	Irrigation costs (irric)	*yuan*/*mu*	180.00	0.00	57.35	39.39	0.69
Determinant	d_1	Age of farm head (age)	*year*	78.00	31.00	49.54	7.02	0.14
	d_2	Schooling length of farm head (edu)	*year*	15.00	5.00	9.11	2.26	0.25
	d_3	Number of agro-labor (labor)	*person*	5.00	1.00	2.42	0.72	0.30
	d_4	Size of farmland (land)	*mu*	20.00	1.00	6.19	3.94	0.64
	d_5	Ratio of irrigable farmland (irril)	%	100.00	0.00	83.13	27.29	0.33
	d_6	Power of agro-machinery (pw)	*kw*	24.99	0.00	6.02	5.49	0.91
	d_7	Public agricultural subsidies (subs)	*yuan*/*mu*	140.00	30.00	68.99	24.29	0.35
	d_8	Gender of farm head (gender)	*dummy*	1=male, 0=female; 94 (94.95%) farms with d_8=1				
	d_9	Multiple cropping (mulc)	*dummy*	1=yes, 0=no; 77 (77.78%) farms with d_9=1				
	d_{10}	Growing of cash crops (cashc)	*dummy*	1=yes, 0=no; 30 (30.30%) farms with d_{10}=1				
	d_{11}	Access to credit market (credit)	*dummy*	1=yes, 0=no; 19 (19.19%) farms with d_{11}=1				
	d_{12}	Access to public service (pubs)	*dummy*	1=yes, 0=no; 32 (32.32%) farms with d_{12}=1				

[a] Note: as a main unit of currency and land measurement in China, 6.627 yuan = 1 US$ (middle exchange rate of 2010), 1 *mu*=666.67m^2.
Data source: farm survey by the authors

In this chapter, we include four categories of variables to identify the effects of these factors: (1) Information of human resources, including age (d_1), gender (d_8), and schooling length (d_2) of the farm heads, and number of agro-labor (d_3) in each farm. (2) Cultivation of land resources, as size of farmland (d_4), ratio of irrigable farmland (d_5), multiple cropping (d_9) and growing of cash crops (d_{10}). (3) Physical and monetary capitals, including power of agro-machinery (d_6), and public agricultural subsidies (d_7). (4) Social and political factors, as access to credit market (d_{11}) and access to public services (d_{12}) by each farm in latest 3 years.

5.3 Efficiency analysis with DEA

5.3.1 Total, technical and scale efficiencies

The efficiency summary in Table 5-2 shows that, within the 99 household farms, 35 farms (Type I) are scored 1 in total, technical and scale efficiencies, thus being deemed as in the status of full efficiency and benchmarks for the other inefficient farms. Furthermore, within the rest 64 farms with total efficiency less than 1, 11 farms (Type II) bear technical efficiencies equaling to 1. It indicates that in these farms, adjustment of any input will not change the efficiency, thus adjusting their farming scales is the only solution to improve production efficiency. Meanwhile, there are still 53 farms (Type III) have technical efficiencies scoring less than 1, indicating that with given farming scales, efficiency can be improved through input reduction.

In terms of the statues of scale efficiency, all the efficient farms are in the status of constant returns to scale, while most of the inefficient farms are being increasing returns, although some of them embrace decreasing returns to scale (Table 5-2). Thus the enlargement of scales is necessary for most of the sampled farms.

Table 5-2 Efficiency summary by DEA

Type	Number of farms	Means			Number of farms with		
		Total efficiency	Technical efficiency	Scale efficiency	*crs*	*irs*	*drs*
I	35	1.000	1.000	1.000	35	0	0
II	11	0.891	1.000	0.891	0	10	1
III	53	0.619	0.682	0.907	0	46	7
Total	99	0.784	0.830	0.938	35	56	8

Note: *crs* = constant returns to scale; *irs* = increasing returns to scale; *drs* = decreasing returns to scale

Software: DEAP 2.1

5.3.2 Slack analysis of the outputs

Slack of an output shows the margin that a firm can improve its output through the adjustment strategies proposed by DEA. The output slacks summarized in Table 5-3 show that, within the 53 farms of Type III, comparing with the absolute output of net profit from agricultural production, the relative output of ratio of net profit can be increased with a larger margin. It indicates that in addition to maintain and increase the price of agro-products, much more endeavors are needed to reduce the costs, cultivate the possible marketing values of agro-products.

Table 5-3 Slack analysis of outputs in farms of Type III

	Net profit of agricultural production (*yuan*/*mu*)			Ratio of net profit (%)		
	Origin1	Target1	Slack1	Origin2	Target2	Slack2
Slack movement	1118.386	1181.860	63.501	65.821	77.374	11.553
% of slack	100.00	105.678	5.678	100.00	117.551	17.551

Software: DEAP 2.1

5.3.3 Radial and slack analysis of the inputs

As implicated by A. Martine, *et al* (2003), the slacks indicate inputs in excess supply, i.e., a smaller percentage of slack movement shows the input is used more efficiently. Within Type III, farming time and agro-machinery rent are used most efficiently, showing the general trend of labor transferring to non-agricultural sectors and the large space of extending agro-machineries. Irrigation cost is measures as with the largest slacks, indicating the unbalanced development of irrigating facilities. Meanwhile, the large slacks of fertilizer and pesticides reveal the excessive application of agro-chemicals.

Table 5-4 Radial and slack analysis in farms of Type III

		Time (*day*/*mu*)	Seeds (*yuan*/*mu*)	Fert (*kg*/*mu*)	Pesti (*kg*/*mu*)	Machr (*yuan*/*mu*)	Irric (*yuan*/*mu*)
Mean movements	Radial	1.192	48.546	25.339	0.272	25.337	22.990
	Slack	0.182	18.910	7.796	0.136	5.790	20.290
	Total	1.374	67.457	33.135	0.408	31.127	43.280
Percent of movements (%)	Radial	33.146	37.141	33.111	30.660	33.817	33.514
	Slack	5.051	14.468	10.187	15.358	7.727	29.578
	Total	38.197	51.609	43.298	46.018	41.544	63.092

Software: DEAP 2.1

5.4 Effects of the determinants on technical efficiencies

5.4.1 Ordinal logistic regression

In cases of the dependent variables are put in ordinal categorical responses, the ordinal logistic regression model can be applied to measure effects of the determinants (A. Uzmay, *et al* 2009; P. Maria, *et al* 2010). Considering k+1 ordered categories, the basic models are defined as:

$$\mathrm{P}(Y \le i) = p_1 + p_2 + \ldots + p_i \qquad (i=1, 2, \ldots, k) \qquad (5\text{-}1)$$

$$odds\ (Y \le i) = \frac{P(Y \le i)}{1 - P(Y \le i)} = \frac{p_1 + p_2 + \cdots p_i}{p_{i+1} + p_{i+2} + \cdots + p_{k+1}} \qquad (i=1, 2, \ldots, k) \qquad (5\text{-}2)$$

$$logit\,(Y \le i) = ln\left(\frac{P(Y \le i)}{1 - P(Y \le i)}\right) = \alpha_i + \beta_{i1} X_1 + \beta_{i2} X_2 + \cdots + \beta_{im} X_m \qquad (i=1, 2, \ldots, k) \qquad (5\text{-}3)$$

where α_i and β_{ij} represents the threshold (j=1, 2, …, m) parameters; X_{ij} are sets of factors or predictors. Eq.5-3 is a general ordinal logistic model for m predictors with k+1 ordered response variables. This model depends on cumulative probabilities of the dependent variable categories, and contains a large numbers of parameters as there are k equations and one set of logistic coefficient β_{ij} for each category (B. Ralf, *et al* 1997; K. A. Adeleke, *et al* 2010).

However, in case of the responses are fabricated from continuous variables, like the farm categories grouped respect to the technical efficiencies by DEA model in this study, a more parsimonious model is applicable. We can assume a parallelism between regression functions of different categories and logit scales (A. Uzmay, *et al* 2009). Namely, the logistic coefficients do not depend on i, but have one common parameter β_j for each covariate. It follows that cumulative odds model is given by:

$$odds\ (Y \le 1) = exp(\alpha_i)\ exp(\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m), \qquad (i=1, 2, \ldots, k) \qquad (5\text{-}4)$$

which means that the k odds for each cut-off category i differ only with regard to the intercepts α_i. Therefore, the effect of a covariate can be quantified by one regression coefficient, and the calculation for one common *odds ratio* is possible, thus the presentation of results is shorter and simplified (B. Ralf, *et al* 1997).

5.4.2 Model selection

In order to conduct an ordinal logistic regression, the sampled 99 household farms are divided into seven groups, in terms of their technical scores provided by DEA. The summary statistics for each group are given in Table 5-5.

Like applying the other regression models, it is necessary to detect the possible interactions through correlation test between the predictors. As the Pearson correlation matrix of the determinant variables shown in Table 5-6, statistically significant correlations occur in 10 pairs of predictors. The significant correlation indicates underlying strong interaction, which affects the accuracy to model the relationship of the predictors and the responses. Therefore, based on the significantly correlated determinant variables, 10 covariates are constructed and put into the ordinal regression model, thus number of the predictors increased to 22 in total.

Table 5-5 Case processing summary statistics

Group	Technical Score [a]	N	% of N	Max	Min	Mean	Std.D	C.V.
1	0.40-0.50	7	7.10	0.497	0.430	0.458	0.026	0.058
2	0.50-0.60	13	13.10	0.594	0.508	0.559	0.026	0.046
3	0.60-0.70	9	9.10	0.696	0.601	0.646	0.026	0.041
4	0.70-0.80	6	6.10	0.778	0.723	0.754	0.021	0.028
5	0.80-0.90	15	15.20	0.892	0.807	0.853	0.024	0.028
6	0.90-1.00	2	2.00	0.939	0.935	0.937	0.003	0.003
7	1.00	47	47.50	1.000	1.000	1.000	0.000	0.000
Total		99	100.00	1.000	0.430	0.833	0.194	0.232

Note: [a] the upper limit is not included in each group

Software: SPSS 13.0

Maximum likelihood estimation of a proportional odds model is carried out through application of the Ordinal Logistic Regression procedure in SPSS 13.0. The stepwise backward approach is applied to remove the statistically insignificant variables (p-value≥0.1), from the initial model with all the 22 determinants as independent variables. Although the covariate of *Crtps* is included, all the VIF (Variance Inflation Factor) in Table 5-7 are less than 2, thus eliminated the possibility of multicollinearity (Y. Murase, *et al* 2007). The final model includes 5 predictors, all of which embrace p-value less than 0.1. Assumption of parallelism is confirmed where we accept the null hypothesis of equal location parameters (slope coefficients). The Chi-square value of 12.377 at the freedom degree of 25 is not statistically significant, hence the assumption of parallelism is satisfied (K. A. Adeleke, *et al* 2010). Meanwhile, the model fitting information (p-value=0.000) shows that the null hypothesis should be rejected, and at least one of the regression coefficients in the model is not equal to zero at the alpha level of 0.01 (Table 5-7). Therefore, the model fits well relationships of the independents and dependents.

Table 5-6 Pearson correlations of the determinant variables

	Age	Edu	Labor	Land	Irril	Pw	Subs	Gender	Mulc	Cashc	Credit	Pubs
Age	1	-0.304**	0.174	-0.010	-0.176	-0.010	-0.073	-0.174	-0.001	-0.051	-0.03	0.139
Edu		1	-0.200*	-0.049	0.147	-0.027	0.010	0.011	0.07	0.143	0.01	-0.159
Labor			1	0.041	0.177	-0.175	0.152	-0.122	0.148	-0.146	-0.074	0.165
Land				1	0.106	0.387**	0.051	0.088	0.028	0.324**	0.043	0.02
Irril					1	-0.141	0.315**	-0.143	0.239*	0.107	-0.095	0.156
Pw						1	0.062	0.000	0.096	.297**	0.226*	-0.169
Subs							1	-0.188	0.329**	-0.033	0.126	0.032
Gender								1	-0.123	0.052	0.112	-0.038
Mulc									1	-0.176	-0.048	0.006
Cashc										1	0.069	-0.08
Credit											1	0.212*
Pubs												1

Note: ** and * represent statistical significance in the level of 5% and 10% respectively

Software: SPSS 13.0

Table 5-7 Parameter estimates of ordinal logistic regression

	Estimate [a]	Std. error	Wald	*df*	*sig.*	odds ratio	Collinearity Statistics [c]	
							Tolerance	VIF
Age	0.136***	0.035	15.540	1	0.000	1.146	0.927	1.079
Labor	-1.059***	0.300	12.494	1	0.000	0.347	0.941	1.063
Gender	1.712*	0.908	3.557	1	0.059	5.539	0.952	1.050
Pubs	-1.387***	0.486	8.143	1	0.004	0.250	0.731	1.368
Crtps	2.210***	0.811	7.429	1	0.006	9.112	0.750	1.334

Test of parallel lines [b]: LR Chi-square(25)=12.377; Sig.=0.983

Model fitting information: LR Chi-square(5)=34.385; Sig.=0.000

Note: *** and * represent statistical significance in the level of 1% and 10% respectively; [a] *crtps* is a covariate constructed based on *credit* and *pubs*; [b] The null hypothesis states that the location parameters (slope coefficients) are the same across response categories; [c] Collinearity Statistics are calculated from the linear regression model using same dependent and independent variables (S. Menard, 2002).

Software: SPSS 13.0

5.4.3 Results and discussion

In Table 5-7, the *Estimate*s are the ordered log-odds regression coefficients, of which the standard interpretation is that for a one unit increase in the predictor, extends that the response variable levels are expected to change in the ordered log-odds, while the other variables are held constant (J. Bruin, 2006). For instance, the estimate of age means that, if a farm were to increase the head's age by one year, his ordered *log-odds* of being in a higher category of technical efficiency would increase by 0.136 while the other variables held constant. The Wald statistic is the square of the ratio of the coefficient to its standard error. The odds ratios of the predictors are calculated by exponentiating the estimates (*i.e.*, odds ratio=e^{β}), thus they indicate probabilities of the response variable level changing to a higher score, due to one unit increase of the predictor. Meanwhile, the lower and upper bounds of odds ratio for each predictor are listed as Confidence Interval (CI), under the confident level of 0.95.

According to the coefficients, *age*, *gender*, and *crtps* increase, while *labor* and *pubs* reduce the odds of a farm be measured to a more efficient group, (J. N. Marija, 2010). In other words, the sampled farms with aged and male head are more probably to be efficient, while the number of agro-labor is negative to agricultural production efficiency. Moreover, the integration of public services with farms' access to the credit market is positive to agricultural production efficiency. These findings are testified by comparison of farms in different groups (Table 5-8).

Table 5-8 Descriptive comparison of farms in different groups

Determinant	Age of farm head						Gender of farm head	
Group	<40	[40, 45)	[45, 50)	[50, 55)	[55,60)	≥60	0	1
Number of farms	4	12	39	23	13	8	5	94
Mean of tech	0.523	0.790	0.855	0.866	0.772	0.954	0.686	0.841

Determinant	Number of agro-labor					Pubs		crtps	
Group	1	2	3	4	5	0	1	0	1
Number of farms	2	63	25	8	1	67	32	89	10
Mean of tech	1.000	0.853	0.828	0.693	0.490	0.854	0.790	0.825	0.905

Software: Excel 2007

(1) Effects of age and gender of the farm heads.

The positive relationship of technical efficiency and farm heads' age is demonstrated in Table 5-8, together with the larger average efficiency score of farms headed by males. The positive effects of these two predictors indicate that in the sampled areas, farming are mainly relying on personal experiences, using traditional production modes or simply imitating the others (L. Wang, *et al* 2003). This result is in line with Z. Chen, *et al* (2009) and S. Tan, *et al* (2010), concluding that farmers with more farming experiences (measured by the household heads' age) have greater farm technical efficiency, consistent with a large amount of information. The professional human resources being able to cultivate and apply agricultural technology are highly needed for efficient farming activities.

(2) Effects of agro-labor numbers

This negative effect from number of agro-labors indicates the existence of surplus labor in Chinese agriculture, being consistent with the findings of Chapter 2, Z. Chen, *et al* (2009) and H. Dong, *et al* (2010). In this survey, the sampled farms have 2.42 agro-labors in average, while the mean farming time spent per mu is only 3.74 standardized days. Therefore, the continuing transfer of surplus labor from agriculture to the other sectors is still of great importance in China.

(3) Effects of access to credit and public services

In this survey, within the latest three years, the farms got public services mainly from the local government and their branches, including the extension of new varieties of agricultural products, aids of setting up cash crop facilities, unified purchase of farming goods, etc. However, as average scale of farmland is less than 0.5 hectare per farm, and farmers are poor with expert knowledge of modern agricultural production. Thus the new farming modes and varieties are difficult to be efficiently extended. On the contrary, they may increase the financial burden of farmers or break their accustomed farming modes and undermine the production efficiency. Hence a negative relationship is found in the aforementioned analysis.

However, when analyzing with *crtps*, the odds of increasing efficiency with farms who have incorporated the effects of farms' accessed to both the credit market and public services, is doubled three times than the farms who have not (Table 5-7). Comparing from the technical scores, the former group (*crtps*=1) scored higher than the latter (crtps=0, Table 5-8). S. Tan, *et al* (2010) demonstrated the importance of credit availability in improving technical efficiency of rice farming in China. It shows that the integration of credit supply and public services are indispensable to improve agricultural production efficiency for the farms.

5.4.4 Discussion on the other determinants

Although modeled as insignificant in the ordinal logistic regression model, the other determinants are still affecting the production efficiency and need to be examined for referential implications.

(1) In the first category of human resources, schooling length of the farm heads is the only determinant being excluded as significant to production efficiency. This result verifies the aforementioned reality that agricultural production is carrying out mainly relying on farmers' private experiences, rather than the adoption of advanced technologies. Hence for most farmers, knowledge learnt at school do not make much difference in improving their agricultural production efficiency.

(2) The second category do not pass the significant test, showing that sizes of farmland sampled are not large enough for the adoption of more efficient farming modes, including the large machineries and modern managerial strategies, i.e., cannot generate scale economy. For farms with irrigable farmland less than 100 percent, the average technical efficiency scored 0.879, larger than that of the farms with all the farmland irrigable. The reason behind is that in most cases, all farmland irrigable means good natural condition and thus larger population and smaller plots of farmland. In this survey, average farmland sized 6.56 *mu* with farms having part of irrigable land, while 5.97 *mu* with farms embracing totally irrigable farmland. Moreover, the insignificant contribution of multiple cropping and growing of cash crops may due to extensive cultivation of resources, especially water, fertilizer, etc. For example, in this survey, the multiple cropping farms use 69.3 *kg* fertilizer for each crop per *mu*, which is 19 *kg* more than single cropping farms; the farms growing cash crops spend 32.92 percent in irrigating and use 32.03 percent of pesticides, more than those growing only grain crops.

(3) For the physical and monetary capitals, as to the insignificant effects of agro-machinery, its connecting with low efficiency of mechanical operations out of the small sized farmlands as mentioned above. For public agricultural subsidies, the

insignificancy may result from the relative low ratio in farms' total cost (as 13.91 percent in this survey). The average technical efficiency score for farms subsided more than 100 yuan per *mu* is 0.933, while 0.822 amongst farms subsided no more than 100 yuan per mu. This result shows the necessity of improve the amounts of agricultural subsidies. X. Yang, *et al*. (2010) concluded similarly that most of the farms in their survey claimed more agricultural subsidies and the funds should be granted to the real grain-growing farms, rather than distributing out simply according to sizes of farmland.

(4) In the fourth category of social and political factors, no significance captured from access to credit market by the ordinal logistic regression model. However, in the farms accessed to the credit market within latest three year, the average technical efficiency scored 0.873, which is larger than the value of 0.824 with farms who did not access. The causes of relatively poor efficiency of credit market include the lack of effective projects and managerial strategies supported public services. Meanwhile, some farms loaned for non-agricultural affairs, while many farms borrowing from relatives as surveyed by G. T. Calum, *et al* (2010).

5.5 Conclusions and recommendations

5.5.1 Main conclusions

This study measures the agricultural production efficiency in Hebei Province, China, through the adoption of DEA and ordinal logistic regression models. According to the efficiency scores of DEA, the 99 sampled household farms are divided into 3 types. In Type I, the 35 farms are fully efficient and in the status of constant returns to scale, thus can be esteemed as benchmarks for the other farms. In the 11 farms of Type II, due to the technical scores fixed to 1, adjustment of any input will not change the output efficiency, thus production efficiency can only be improved through expanding the managerial scales in 10 farms, while compressing in one farm. Meanwhile, in the 53 farms of Type III, production efficiency can be improved through either reducing some of the inputs or adjusting the managerial scales with expansion in 46 and compression in 7 farms.

The output slacks show that comparing with net profit, ratio of net profit can be increased with a larger margin. Percentages of input slacks show that farming time and agro-machinery rent are used with highest efficiency, while irrigation cost is supplied with largest excess, following by seeds, pesticides and fertilizer.

In the second stage, significant coefficients of the ordinal logistic regression model show that farms with aged and male head are more probably to be efficient, the increasing of agro-labor has negative effects, and the public services do not improve the agricultural production efficiency, unless it is conducted with farms' access to credit market.

5.5.2 Policy recommendations

(1) On the basic production factors. As more than half of the sampled farms are in the status of increasing returns to scale, and size of farmland sampled is demonstrated as not large enough for generating scale economy. Being the major measurement of farming scale, farmland size should be increased through accelerating the circulation and concentration of land-use right among farms. In China, as land is performing as self insurance of subsistence, farmland should be concentrated on farmers' own will, through favorite subsidies.

Considering the negative effects of aro-labor numbers, surplus labors need to be further transferred from agriculture to the other sectors. The major obligations for the government include promoting the implementation of Sunlight Project, perfecting the construction of employment information networks, and protecting the legal rights of migrant workers. Meanwhile, as the farmers are mainly relying on personal experiences and traditional modes or imitating the others, advanced agricultural techniques and managerial strategies should be introduced into the vocational training of Sunlight Project, hence improve their farming efficiency.

(2) On the other production factors. To tackle with the large slacks in pesticides and fertilizer, instruction on proper use of agricultural chemicals should be strengthened. Priorities should be placed on the field tests thus decide the appropriate amounts and balanced ingredients. The manufacturers, research institutes, etc, can play critical roles in terms of technical supporting, through innovating and extending their services to farmers (H. Han, *et al* 2009). As proposed by R. Hu, *et al* (2009), separating commercial activities from the agricultural sci-tech extension agencies and corresponding subsidies are important as well. Hence these institutions can benefit from the applicability of their research achievements in improving production efficiency of farms.

Being another important factor, high quality seeds should be guaranteed. In spite of the conducting public funds that subsiding the using of quality seeds by the farms, they are generally being distributed simply based on the areas of farmland in practice, as it is difficult to make sure that the subsided farms are used the quality seed (X. Yang, *et al* 2010). Therefore, the government should subsidize R&Ds on quality seeds directly, and strengthen the supervision of seeds markets, thus guarantee the quality and reduce the costs simultaneously.

(3) On the construction of public agro-facilities. Since irrigation costs embraced the largest slacks, the quality of irrigation facilities is of great importance to improve production efficiency. The governments should invest more fiscal funds and channel more social capitals to the construction of irrigating and water conservancy facilities. Priorities should be placed on the efficient usage of water and cutting down the

irrigating costs.

(4) On the public services. Closer integration of the aforementioned public services and efficient credit market needs to be accelerated. The rural financial institution should be encouraged in innovating institutions on granting credit to farmers, such as granting loans with mortgage on land-use right, taking external permanent staffs as guarantors, etc. Moreover, public services concerning credit access can be entrusted to the farmers' cooperatives, which are developing quickly in latest years, thus improve the credibility of farmers and increase the funding efficiency.

5.5.3 Open research topics

In the future researches, if the survey can be expanded to a larger region or even the whole country, taking more specific items to included crop-based inputs. Thus production efficiency of comparison of different regions and crops can be realized. In addition, special study can be conducted with focuses on the enlargement of farming scales, especially farmlands, proper use of agricultural chemicals, construction of public agricultural facilities, etc. Moreover, years of continuous study will provide a valuable database for the exploring laws of agricultural production efficiency, hence be referential for further policy recommendations.

Chapter 6 Farmers’ Application of Fertilizers from Six Eastern Provincial-level Regions

6.1 Introduction

As one of the elemental inputs to agriculture, increasing application of fertilizer has been demonstrated as a key factor in improving China’s agricultural productivity over the latest decades (J. Y. Lin, 1992; D. Li, *et al* 2011b). In 2009, the chemical fertilizer applied to agriculture amounted to 54.04 million *ton*s in China, maintained an average annual growth rate of 6.01 percent since 1978 (CNSB, 2011). Meanwhile, the excessive use of fertilizer, especially Nitrogen fertilizer, has resulted in serious threats and losses on ecological environment, human health and economic development. In 2008, the fertilizer consumption was 467.98 *kg* per hectare of arable land, much larger than the average amount of 134.93 *kg* per hectare amongst the 175 countries (World Bank, 2011). Field test has revealed the low fertilization efficiency in China: the average Nitrogen absorption efficiency of wheat, corn and rice are 28.3 percent, 28.2 percent and 26.1 percent, far lower than that of 40-60 percent in the European and American countries (F. Zhang, *et al* 2008). Furthermore, even lower Nitrogen absorption efficiency of only 10 percent exists in vegetables, fruits and flowers (W. Zhang, *et al* 2004). According to Bulletin of the First National Census on Pollution Sources issued in 2010, the non-point pollution (NPP) of agriculture has become the first source of water contamination in China, while chemical fertilizer applied in crops production constitutes the main source of agricultural NPP. The large volume of fertilizer residues has become a major source of environmental pollution and food safety incidents, thus proper application of fertilizer is drawing unprecedented public concerns. Chinese government has adopted the control of agricultural NPP into the 12th Five-year Plan (2011-2015), with strengthening regulations on fertilizer.

As household farms are the overwhelming managerial units in Chinese agriculture, the understanding of their behaviors and determinants is vital for the combats to agricultural NPP. Although many scholars have conducted concerning studies, there are still a variety of topics need to be researched with further depth. (1) In terms of the survey area, Q. Gong, *et al* (2008) surveyed 295 farms from 27 villages of 3 prefectures, Hubei Province; H. Han, *et al* (2009) surveyed 177 farms in Xinxiang County, Henan Province; C. Yin, *et al* (2010) studied the farmers’ willingness to reduce amounts of fertilizer used on the crops through sampling 120 farms in Nanjing Prefecture, Jiangsu Provinces. If more farms from a larger scope of regions be sampled, the findings and conclusions will be more representative to capture their behaviors and important factors of fertilizer application. (2) Some scholars oriented their studies to the fertilizer application on grain crops, including corn and wheat (H. Han, *et al* 2009; Z. Zhang, *et al* 2011), rice (B. Yan, 2010), etc. However, most of the farms are growing several agricultural products, on which the fertilizer applications are affecting each other, due to limited household budgets, personal preferences, etc. Besides the grain crops, information on cash and other plants should be included, to benefit the overall understanding of farmers' application of fertilizer. (3) In China, farmers have the tradition of using organic fertilizer, behaviors of which may be affected by a variety of factors, including the breeding of livestock and poultry. Thus for a full scenario of fertilization in different farms, it is necessary to obtain information on both the organic fertilizer and significant determinants. (4) Due to the differences in biological species and soil properties, the appropriate amounts of fertilizer are varying amongst different plants and regions. Based on the China Fertilizer Regionalization, Z. Liu, *et al* (2008) and Z. Yang, *et al* (2011) included the effects of soil conditions in different regions in their analyses of agricultural fertilization. However, most of the studies compared the behaviors and conception on fertilization amongst farms, without the consideration of impacts from the geographical locations and planting structures. To isolate impacts from these factors, more comprehensive indicator systems or specifications are necessary to be introduced. (5) With respect to measurement of farmers' behaviors, some scholars used the willingness of applying organic fertilizer (X. Zheng, 2010), reducing amounts of fertilizer (C. Yin, *et al* 2010), while in some other studies, the behaviors are represented by amount of Nitrogen fertilizer (Q. Gong, *et al* 2008), willingness of adopting soil-testing technologies (H. Gao, *et al* 2011), etc. However, the physical amount of chemical fertilizer, with the consideration of geographical locations and planting structure, is indispensible to analyze farmers' behaviors and conceptions. Furthermore, the integrated analyses on the determinants of farmers' application of organic fertilizer, their perceptions and requirements, etc., will be much beneficial for policy recommending.

Therefore, based on the survey to 560 household farms of eastern China's 6 provincial-level regions, this study defines farmers' behaviors including total amount of chemical fertilizer, use of organic fertilizer. All the major agricultural products are surveyed and analyzed, including wheat, corn, rice, cotton, fruiters, vegetables, oilseed and peanut. The perceptions investigated cover a variety of concepts from choosing the fertilizer, field application to the possible consequences of over fertilization and disposal of the used packages. To explore significant determinants behind the behaviors, both quantitative and dummy indicators are used to represent predictor and response variables, through the application of binary logistic regression models. The remainder of the chapter is organized as follows: the next section briefly describes the field survey and the basic statistical summaries; Sections 3 and 4 analyze determinants on farmers' behaviors towards fertilizer application; in Section 5, conclusions and policy recommendations are presented, followed by open research topics.

6.2 The field survey

6.2.1 Sample and method

To understand the present situation and farmers' perceptions on agricultural pollution, we conducted the survey with questionnaire-based personal interviews to collect first-hand data as used in many previous studies (e.g., Q. Gong, *et al* 2010; H. Gao, *et al* 2011). In the first section, our questionnaire contains basic characteristics of each household farm, including demographic information of family members, annual incomes, scale and planting structure of farmland, production and marketing of aro-products, etc. In the second section of the questionnaire, we inquire the disposal of life garbage, including the wasted glasses, plastics, paper and clothes; kitchen and manure garbage, etc. In succession, farmers' selection and application of fertilizer, pesticides and veterinary drugs are enquired. In the final section, we collect farmers' perceptions on the major sources, routes, responsible parties and countermeasures of agricultural pollution, information and recognition on safe agricultural products (Appendix II).

In January to March, 2011, we surveyed 560 household farms in 21 villages of eastern China's 6 provincial-level regions, including Beijing, Hebei, Shandong, Shanghai, Jiangsu and Zhejiang (Fig.6-1). The sampled area covers 3 major gains-growing provincial-level regions, and rural regions affiliating to the top two metropolises in China. The former three regions represent the northern mode of Chinese agricultural production in the Yellow River Basin, while the latter three demonstrate the characteristics of agricultural production in south China' Yangtze River Basin. Viewing from the topographic types, farms locating in plain, hills and mountainous regions, villages in inlands, seaside and adjoining the metropolises are sampled. In addition to the staple grains crops of wheat, rice and corn, the other major agricultural products, including cotton, vegetables, fruiters, oil crops, etc, and the main livestock, poultry, aquaculture products are being grown and bred in the sampled farms.

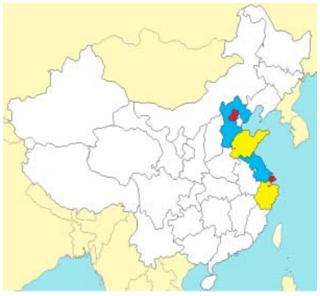

Fig. 6-1 Location of the sampled areas

Source: revised based on http://www.chinamapxl.com/

6.2.2 Theoretical model

Drawing upon the rural household models of W. E. Huffman (2001), farmers are assumed to make consumption, production and labor supply decisions by maximizing utility from a home-produced good Y_1 and leisure L:

$$U = U\ (Y_1, L) \tag{6-1}$$

subjecting to technology constraints from the production function (Eq.6-2), human time constraints (Eq.6-3), and cash income constraints (Eq.6-4):

$$F\ (Y_1, Y_2, Y_3, H, X, A, E) = 0, \qquad Y_3 \geq 0, X \geq 0 \tag{6-2}$$

$$T = L + H + H_m, \qquad H_m \geq 0 \tag{6-3}$$

$$I = P_2 Y_2 + P_3 Y_3 + W_m H_m + V = W_X X \tag{6-4}$$

where Y_2 and Y_3 are outputs produced for sale, the market prices of which are P_2 and P_3, respectively; total available time per production circle T is allocated among leisure L, farm-household work H, and off-farm wage work H_m with the market wage rate *of* W_m; X represents purchased variable inputs, with the price vector of W_X; A is technology and agro-climatic conditions; E is an education index of household decision makers; within the cash income of I, V is the household nonfarm-nonlabor income net of any fixed costs associated with farm-household production.

To analyze farmers' application of fertilizer (F_f), production decision on a certain variable input (X), four types of variables are included to depict major constraints of household farms in our model:

$$F_f = F\ (HR, LC, HI, GL) \tag{6-5}$$

As household is the most important member in decision-making, the category of human resources (*HR*) consists of variables on age, gender and education level (*E*) of the households. As the production function Eq.6-2 permits adopting new inputs (W. E. Huffman, 2001) and land in the basic means in agro-production, two variables on land cultivation (*LC*) are adopted. In the variables on household incomes (*HI*), total cash income constraint (*I*) is represented by annual cash incomes, while off-farm wage work H_m is described with the ratio of migrant incomes. Finally, as geographic location (*GL*) affects the technology and agro-climatic conditions (*A*), market wage of the off-farm work (W_m) and prices of the inputs (W_x), three variables are included to show farms' affiliation to the metropolises, the north or south, and location in the National Fertilization Regionalization. Variables in each type and mechanism of modeling farmers' use of fertilizer are shown in Fig.6-2. In addition, impacts of planting structure will be analyzed later, through the specification of Fertilization Coefficient as Eq.6-6.

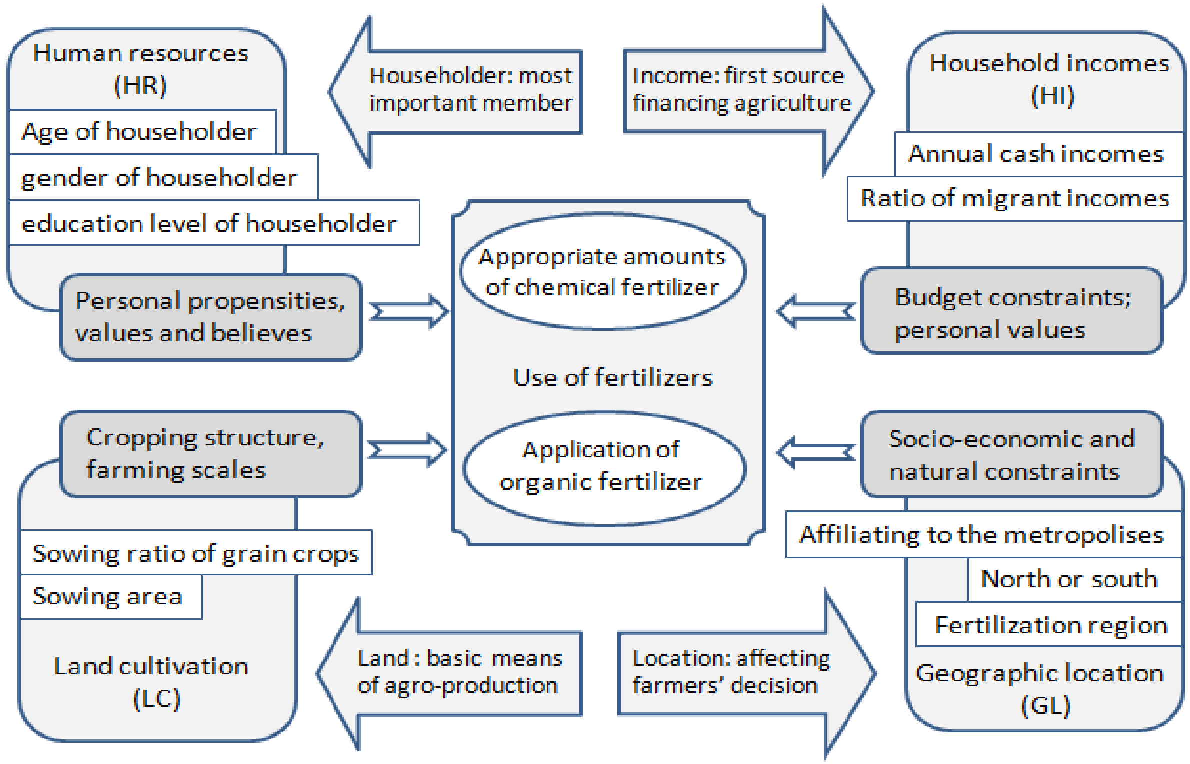

Fig. 6-2 Mechanism of modeling farmers' use of fertilizer

6.2.3 Demographic characteristics

In this study, only farms answered as used fertilizer in 2010 are included, thus the sample consists of 294 valid responses from this survey. Based on the theoretical model specified above, we include 10 indicators to represent the demographic characteristics of each farm (Table 6-1). Simultaneously, these indicators will be used as candidate determinants to interpret farmers' behaviors on fertilizer application.

(1) Considering the importance of householders in making productive decisions within household farms, many studies included concerning variables as determinants in the analysis of safe agricultural production. In this study, we include three variables to describe attributes of the householders, i.e., human resources (*HR*), as *gender* (Q. Gong, *et al* 2010), *age* (H. Gao, *et al* 2011) and education level (*edu*, H. Han, *et al* 2009).

(2) In agrarian societies, land is not only the main means for generating livelihood, but often also for accumulating wealth and transferring it between generations (K. Deininger, *et al* 2001). Thus two continuous variables on land cultivation (*LC*) are introduced: the sowing area of total agricultural products (*scale*), rather than total area of farmland is adopted with the consideration of multiple cropping (H. Wang, *et al* 2004); sowing ratio of grain crops (*grainr*) is included to identify the effects of land use structure.

(3) Meanwhile, another two variables are introduced to measure impacts of discrepancies in household income (*HI*): total annual cash income (*income*) affects household budgets and thus inputs to agriculture, including the purchase of fertilizer (H. Han, *et al* 2009; H. Gao, *et al* 2011); ratio of income from migrant job (*mir*) shows the main sourcing structure of household income, which affects the relative importance of agriculture and the corresponding inputs as well (H. Dai, 2010).

(4) To model the influence of geographic location (*GL*) on farmers' application of fertilizer (J. Ma, 2006), two dichotomous dummy variables are included with *north* (north or south of China) equal to 1 if a farm is from Beijing, Hebei or Shandong, and *metro* (metropolises or not) coded as 0 if a farm affiliates to neither Beijing nor Shanghai. The statistical summary of each variable is shown in Table 6-1. Finally, according to the China National Fertilization Regionalization[1] (Z. Liu, *et al* 2008; Z. Yang, *et al* 2011), the sampled areas cover four sub-regions as shown in the statistics following the characteristic variable of *fregion*.

[1] The China National Fertilization Regionalization is drafted by Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences. According to the soil condition and fertilization characteristics, this national planning divides farmland of China into 31 sub-divisions within 8 divisions.

Table 6-1 Demographic characteristics of the sampled farms applied fertilizer

Characteristic	Type [a]	Unit	N	Mean	Min	Max	Std. D.	C.V.
Age of householder (*age*)	HR	year	288	50.368	26.000	85.000	10.708	0.213
Sowing area (*scale*)	LC	*mu* [b]	294	5.341	0.100	38.000	5.163	0.967
Ratio of grains sowing scale (*grainr*)	LC	%	289	36.845	0.000	100.000	36.702	0.996
Ratio of migrant income (*mir*) [c]	HI	%	281	35.362	0.000	100.000	41.297	1.168
Gender of farm head (*gender*)	HR	dummy	288	1=male (275 [d]); 0=female (13)				
Education level of farm head (*edu*)	HR	dummy	282	1=illiteracy (12); 2=primary (71); 3=middle (149); 4=high (42); 5=advanced (8)				
Total cash income in 2010 (*income*)	HI	dummy	291	1=under 10000 *yuan* (42); 2=10000-30000 *yuan* (105); 3=30000-50000 *yuan* (88); 4=over 50000 *yuan* (56)				
North or south of China (*north*)	GL	dummy	294	1=north (141); 0=south (153)				
Metropolises or not (*metro*)	GL	dummy	294	1= Beijing or Shanghai (74); 0=other regions (220)				
Fertilization region (*fregion*)	GL	dummy	294	1=Yanshan-Taihang mountainous areas (33); 2=Yellow-Huaihe-Haihe Plain (82); 3=Yangtze River plain (106); 4=Foothill areas South of Yangtze River (73)				

Note: [a] referring to the four types of variables shown in Fig.6-2; [b] as a main unit of land measurement in China, 1 *mu*=666.67m^2; [c] the income sources contain migrant jobs and sales of agricultural products; [d] the bracketed numerals denote counts of farms.

Source: field survey by the authors

6.2.4 Behaviors on fertilizer application

To capture the major behaviors of chemical fertilizer application in a farm, in addition to an aggregate amount, quantities of Nitrogen, Phosphate, Potash and Compound fertilizers used in each agro-product are included.

In the sampled farms, the Nitrogen fertilizers mainly include Carbamide, Ammonium bicarbonate, etc; the major Phosphate fertilizer used is Calcium superphosphate; Potash fertilizers are consist of Potassium sulfate, etc. Amongst the three types of macro-element fertilizers, Nitrogen fertilizers are most widely used by 278 (94.56 percent) farms, while Potash fertilizers are used only with 4 (1.36 percent) farms. Although many compound fertilizers contain all the macro elements, the general fertilizing trend of rich Nitrogenous and poor Potash nutrients (Z. Liu, *et al* 2008; Q. Gong, *et al* 2010) is testified from the survey.

Meanwhile, the application of organic fertilizer (mainly including manure and compost) is represented in terms of the counts of farms amongst both the total sample and those who used chemical fertilizer simultaneously (Table 6-2).

The surveyed agro-products include wheat, corn, rice, cotton, fruits, vegetables, oilseed, peanut (Table 6-3). The average fertilizer used in the three main grain crops of wheat, corn and rice is 55.31 *kg* per *mu*, which is much less than that of the other products as 91.60 *kg* per *mu*. Within the three main grain crops, wheat is applied with the largest amounts of fertilizer, while vegetable is mostly fertilized amongst all the other categories of agricultural plants. As to the organic fertilizer, it is much widely used in the three main grain crops than in the other agricultural plants.

Table 6-2 Application of fertilizer in the sampled farms

	Unit	N	Mean	Min	Max	Std. D.	C.V.
Chemical fertilizer	*kg/mu*	294	58.489	8.890	285.710	45.609	0.780
Nitrogen	*kg/mu*	278	34.589	2.140	285.710	34.276	0.991
Phosphate	*kg/mu*	12	29.748	12.820	85.710	20.664	0.695
Potash	*kg/mu*	4	132.500	10.000	200.000	89.954	0.679
Compound	*kg/mu*	194	36.714	4.440	200.000	28.065	0.764
Organic fertilizer used in total farms	dummy	300	1=used (206); 0=unused (94)				
Farms used organic and chemical fertilizer	dummy	224	1=used (137); 0=unused (87)				

Note: the bracketed numerals denote counts of farms.

Source: field survey by the authors

Table 6-3 Application of fertilizer in each agricultural plant

	Application of chemical fertilizer							Farms used
	Unit	N	Mean	Min	Max	Std. D.	C.V.	organic fertilizer
Wheat	*kg/mu*	120	63.928	2.330	333.330	40.107	0.627	50
Corn	*kg/mu*	120	51.159	8.330	175.000	34.749	0.679	50
Rice	*kg/mu*	61	46.505	6.670	220.000	35.997	0.774	30
Cotton	*kg/mu*	32	76.189	5.000	266.670	64.482	0.846	21
Fruiter	*kg/mu*	9	104.153	50.000	285.710	77.292	0.742	26
Vegetable	*kg/mu*	51	120.415	10.000	400.000	101.775	0.845	72
Oilseed	*kg/mu*	41	82.603	10.670	190.000	35.687	0.432	18
Peanut	*kg/mu*	25	62.799	6.000	140.000	33.240	0.529	5

Source: field survey by the authors

6.2.5 Perceptions on fertilizer application

In the questionnaire, 4 questions are concerning farmers' perceptions on fertilizer application, from choosing, applying and determining the amounts of chemical fertilizer, to the consequences of over fertilization. Moreover, as most of the fertilizer bags are made from PVC, containing a variety of toxic cancer-causing substances, long-term storage of food is easy to bring about damp mildew and produce a strong carcinogen of aflatoxin (W. Han, 2005). Thus the improper disposal of fertilizer containers may endanger environmental safety and human health, farmers' disposal of the used fertilizer packages is enquired simultaneously. For each question, the number of valid responses, counts and percents of responses to each choice are shown in Table 6-4.

For most of the farmers, productive effects are the first determining factors in choosing and using fertilizer, less attention is paid upon the environmental effects and sprayers' health. When determine the mounts of fertilizer, more than 50 percent farmers are answered as following package instructions, while some one third of them are relying on their own experiences. In terms to the disposal of used fertilizer packages, almost 60 percent farmers answered as rinsing and reusing, thus pose threats to the environment and human health. In many rural areas, farmers are storing their grains and other food stuffs in the used fertilizer bags, hence make their food in high risk of being contaminated. Some farmers even rinse the used fertilizer bags in rivers, lakes, etc, hence constituting public water contaminations (J. Zhang, *et al* 2007). On the possible consequences of over fertilization, as a multiple-choice question, farms chose soil compaction account for an overwhelming ratio of 68.94 percent, following by another choice of crop lodging with 45.78 percent. As to water contamination, it is chosen by only less than one third of the respondents.

Table 6-4 Perceptions concerning fertilizer application

1. Determinants on choosing of fertilizer (Single-choice with 546 valid responses)					
Price	Productive effects	The sellers	Peer practices	Follow-up services	Environmental effect
103 (18.86%)	380 (69.60%)	16 (2.93%)	31 (5.68%)	1 (0.18%)	15 (2.75%)
2. Determinants of using fertilizer (Single-choice with 546 valid responses)					
Costs	Productive effect	Environmental effect	Sprayers' health	Quality of agro-product	
120 (21.98%)	343 (62.82%)	13 (2.38%)	7 (1.28%)	63 (11.54%)	
3. Determinants of fertilizing amounts (Single-choice with 546 valid responses)					
Container instructions	Private experience	Instruction from the extension staff		Peer practices	
278 (50.92%)	191 (34.98%)	42 (7.69%)		35 (6.41%)	
4. Disposal of the fertilizer packages (Single-choice with 555 valid responses)					
Rinsing and recycling	Burning up	Littering	Collective recycling	Others	
326 (58.74%)	33 (5.95%)	57 (10.27%)	133 (23.96%)	6 (1.08%)	
5. Consequences from over fertilization (Multiple-choice with 557 valid responses)					
Crop lodging	Soil compaction	Water contamination	Increasing crop yields	Unknown	Others
255 (45.78%)	384 (68.94%)	148 (26.57%)	85 (12.56%)	39 (7.00%)	17 (3.05%)

Note: numerals are the counts of valid responses, and the bracketed numbers are the corresponding percents of responses.

Source: field survey by the authors

Thus the proper and traditional perceptions are coexisting amongst the farmers, as applying fertilizer by package instructions, concerning on possible soil compaction due to over fertilization, while rinsing and reusing the packages for food-storage, etc.

6.3 Analysis on the behavior determinants

6.3.1 Calculating the Fertilization Coefficient

As aforementioned, the application of fertilizer is mainly affected by three factors: soil properties represented by the geographical location in the National Fertilization Regionalization, agricultural planting structure and farmers' propensities. This study aims to identify the discrepancies amongst farmers in terms of their propensities and thus behaviors on fertilizer application. Hence for further analysis, it is necessary to insulate impacts of the former two factors. In this survey, average amounts of fertilizer applied per *mu* in each ago-product are varying amongst different areas in the National Fertilization Regionalization (Table 6-5).

Table 6-5 Average amounts of fertilizer applied to each ago-product in different regions (Unit: *kg*/*mu*)

Sub-division region	Wheat	Corn	Rice	Cotton	Fruiter	Vegetable	Oilseed	Peanut
Yanshan and Taihang mountainous areas		40.355			285.710			
Yellow river-Huaihe river-Haihe river Plain	64.975	55.229		104.729	118.890	157.097		51.528
Yangtze River Plain	60.485	53.274	54.526	58.5525		84.841	98.844	71.655
Foothill Areas South of Yangtze River			41.302	17.500	59.000	68.75	43.353	

Source: field survey by the authors

To show the pure effect of farmers' propensities on determining amounts of chemical fertilizer, an indicator of *FC* (Fertilization Coefficient) for the *i*-th farm is formulated as:

$$FC_i = \sum_{j=1}^{8}\left(\frac{s_{ij}}{s_i}\cdot\frac{f_{ij}}{f_{\overline{kj}}}\right) \quad (i=1, \cdots, 294;\ k=1, \cdots, 4) \tag{6-6}$$

where s_{ij} is the sowing scale of the *j*-th agricultural product in the *i*-th farm; s_i is the total sowing scale of agricultural plants in the *i*-th farm; f_{ij} is the fertilizer applied per *mu* to the *j*-th agricultural product in the *i*-th farm; $f_{\bar{kj}}$ is the average amount of fertilizer applied per *mu* to the *j*-th agricultural product in the *k*-th region.

The summary statistics of the *FC*s for the 294 valid responses are shown in Table 6-6. To differentiate farmers' behaviors of fertilization driven by their propensities, they are divided into three groups in terms of their *FC*s, and the summary statistics for each group are provided in the same table. Group II embraces *FC*s fluctuating within 50 percent around 1, which represents the moderate amount of fertilizer determined by certain location and planting structure. Meanwhile, farms falling into the Group I and III indicate propensities of applying fertilizer with 50 percent under and over the moderate amounts, respectively. Statistics in this table show that Group II includes 180 farms (61.22 percent) with least coefficient of variance (CV) than the other two groups.

Table 6-6 Summary statistics of FC in different groups

Group	Range	N	Mean	Min	Max	Std. D.	C.V.
I	(0, 0.50)	84	0.310	0.080	0.496	0.107	0.343
II	[0.50, 1.5)	180	0.949	0.500	1.486	0.252	0.266
III	[1.5, +∞)	30	2.133	1.514	3.804	0.588	0.276
Total		294	0.887	0.080	3.804	0.577	0.650

Source: field survey by the authors

6.3.2 On the total amounts of fertilizer

To model the factors significant for the *FC* of a farm falling to any of the Groups above, the dependent variable is a dichotomous indicator being coded 1 if belonging to a certain group and 0 if not. As the OLS models are inappropriate for the discrete and limited dependent variables (J. Jack, *et al* 1997), a Binary Logit Regression model is adopted and formulated as (H. R. Seddighi, *et al* 2000):

$$Log\left[\frac{P(Y_1)}{P(Y_0)}\right]=\beta_0+\sum_{i=1}^{9}\beta_i x_i+\varepsilon \tag{6-7}$$

where $P(Y_1)$ denotes the odds of *FC* belonging to a certain group, while $P(Y_0)$ represents being in other groups; x_1, x_2, …, x_9 are the variables except for *fregion* in Table 6-1; β_0 and β_i are coefficients to be estimated; ε is the random error.

Estimation of the model is carried out through application of the Binary Logistic Regression procedure in SPSS 13.0. Backward approach is adopted to remove the statistically insignificant variables (p-value≥0.1), from the initial model with all the candidate determinants as independent variables. The final model selected includes predictors embracing p-value less than 0.01 (Table 6-7). The column of B estimates log-odds coefficients of β_i in Eq.6-7, for predicting the dependent variable from the independent variables. The last column lists the exponentiation of B, the ratio of $P(Y_1)$ and $P(Y_0)$, thus be called *odds ratios* simultaneously. In this case, an *odds ratio* over 1 denotes that the farm is more probably to fall into the group, while an *odds ratio* less than 1 implies that the farm is easier to falling out of the group (J. Bruin, 2006).

Table 6-7 Binary logistic regression on FC of different groups

Group	Variable	B	S.E.	Wald	df	Sig.	*odds ratio*
I	Age of farm head (*age*)	0.020*	0.012	2.931	1	0.087	1.020
	Total cash income in 2010 (*income*)	0.560***	0.161	12.050	1	0.001	1.751
	Sowing area (*scale*)	-0.087***	0.032	7.275	1	0.007	0.917
	Sowing ratio of grain crops (*grainr*)	0.773**	0.384	4.054	1	0.044	2.166
	Ratio of migrant income (*mir*)	-0.009**	0.004	6.109	1	0.013	0.991
II	Total cash income in 2010 (*income*)	-0.444***	0.144	9.423	1	0.002	0.642
	Sowing area (*scale*)	0.098***	0.030	10.788	1	0.001	1.102
	Ratio of migrant income (*mir*)	0.010***	0.003	7.672	1	0.006	1.010
III	Sowing area (*scale*)	-0.115**	0.060	3.741	1	0.053	0.891

Omnibus tests of coefficients for model I: Chi-square (5)=23.941, Sig.=0.000***

Omnibus tests of coefficients for model II: Chi-square (1)=5.002, Sig.=0.025**

Omnibus tests of coefficients for model III: Chi-square (3)=25.191, Sig.=0.000***

Note: *** and ** represents statistical significance in the level of 1% and 5%, respectively

Software: SPSS 13.0

The results show that, (1) Sowing area (*scale*) is an essential factor occurs in all the three groups, as negative within both I and III, while positive in Group II. It reveals the existence of scale economy in terms of fertilizer application in the sampled farms, thus the increase of managerial scale is favorable for appropriate fertilization (Z. Yang, *et al* 2011). (2) As another significant determinant, total annual *income* is beneficial for the probability of using fewer amounts of fertilizer (J. Ma, 2006). In this survey, apparent positive relationship exists between annual *income* and non-agricultural ratios. Within the farms included in this model, no migrant income occurred in the farms with annual cash income less than 10000 yuan, while this ratio in the other three income levels of Table 6-1 are 26.71 percent, 51.36 percent and 55.54 percent, respectively. The more non-agricultural income usually result in less farming time and attention in agricultural yields, thus the application of fertilizer may be decreased. (3) Meanwhile, the negative effect from income ratio of migrant job (*mir*). Due to the instability and high expenditure of living away from homeland, most of the migrant farmers have to leave their families at home and engage in agriculture. As most of the left family members are women, children, and the elderly, they are prone to improve agricultural productivity through chemical fertilizer. The negative effect of *mir* in Group I may reveals that the more they get from migrant jobs, the more they will be afford to use fertilizer (Q. Gong, *et al* 2010). Meanwhile, due to the lack of prime labors, most of them are not over-fertilization, thus being positive in Group II. (4) The positive effect of *age* in Group I reveals that farms headed by the elderly are easier to fertilize less than the average amounts. It may be interpreted as due to limitation of physical power, disposable income, etc. (5) As analyzed above, the three types of staple grain crops are supplied with less fertilizer than the other agricultural products. Therefore, their sowing ratios (*grainr*) go positively in Group I hence negatively with the total amounts of fertilizer.

6.3.3 On the application of organic fertilizer

With the same Binary Logistic Regression procedure in SPSS 13.0, we measure significant factors for the application of organic fertilizer in the sampled farms. Besides the aforementioned 9 variables, we add three variables into the candidate determinants: amount of chemical fertilizer (*fert*), quantity of *livestock* and *poultry* to capture the possible impacts from these predictors, with the hypothesis that these variables affect farmers' application of organic fertilizer.

As shown in Table 6-8, through the predictor selection method of Backward, six variables are included in the final model. Judging from the *odds ratio* of each variable, impact of each variable can be identified.

Table 6-8 Binary logistic regression on application of organic fertilizer

Variable	B	S.E.	Wald	*df*	Sig.	*odds ratio*
North or south of China (*north*)	-1.265***	0.484	6.820	1	0.009	0.282
Age of farm head (*age*)	0.029*	0.016	3.192	1	0.074	1.029
Total cash income in 2010 (*income*)	0.574***	0.217	6.974	1	0.008	1.775
Sowing area (*scale*)	-0.123***	0.037	11.301	1	0.001	0.884
Sowing ratio of grain crops (*grainr*)	-0.010**	0.005	4.218	1	0.040	0.991
Income ratio of migrant job (*mir*)	-0.026***	0.005	25.254	1	0.000	0.975
Cases included in analysis: 267; Missing cases: 33; Total cases selected: 300						
Dependent variable: whether organic fertilizer is used, with 178 cases = 1, and 89 cases = 0						
Omnibus tests of model coefficients: Chi-square (6)=86.382, Sig.=0.000***						

Note: ***, ** and * represent statistical significance in the level of 1%, 5% and 10%, respectively.

Software: SPSS 13.0

(1) Farms from the north (*north*=1) are less probably to use organic fertilizer. Further investigations are necessary to explore the possible reasons in planting structure, habits, and awareness on the function of organic fertilizer. (2) *Age* of farm head is positive with farmyard application. It may be interpreted as that with the accumulation of social experiences, farmers are more confident about the effectiveness of organic fertilizer, or the significance of properly disposing the feces and urine. (3) Similar with the findings of X. Zheng (2010), annual cash *incomes* is positive with farmyard application as well. With the increase of income, farmers need cleaner environment and safer food supply, thus they are apt to fertilize their farmland with organic fertilizer, rather than chemical fertilizer (as analyzed above). (4) Farms with larger sowing *scale*s are less prone to use organic fertilizer, probably due to the fact that they are pursuing higher production efficiency and tend to use chemical fertilizer. In addition, the collection and application of organic fertilizer enough for their large sowing scales is consuming in labor and funds. (5) Sowing ratio of grain crops (*grainr*) is negative with the application of organic fertilizer, which can be interpreted as most of the grains are sold out while the economic agro-products will be consumed by the farmers themselves. Hence they are tending to fertilize the economic crops with organic fertilizer with are labor-consuming but deemed as salubrious by the farmers (C. Yin, *et al* 2010). (6) Income ratio of migrant job (*mir*) is found negative with the application of organic fertilizer. The main reason behind may be the fact that, farms lying on more the non-agricultural income usually have less time and attention to farming, much less fertilizing their farmland through organic fertilizer. Meanwhile, no significant relationships are detected between the application of organic fertilizer and chemical fertilizer (similar with X. Zheng 2010), breeding of livestock and poultry. It indicates the existence of blindness in application of organic fertilizer, which may bring about improper disposal of manure and compost, thus environmental pollutions.

6.4 Conclusions and Recommendations

6.4.1 Major conclusions

Based on a survey to 560 household farms in 6 eastern provincial-level regions of China, this study explores farmers' behaviors, perceptions and determinants of fertilizer application. The behaviors involve total amount of chemical fertilizer and the use of organic fertilizer; farmers' perceptions are ranging from choosing and field application, the consequences of over fertilization and disposal of the used packages. Logistic regression models are used to identify the significant determinants of their behaviors.

The survey shows that most farms are using Nitrogen fertilizers, while Potash fertilizers are used in few farms. Comparing with the other plants, less chemical fertilizer are used in the main grain crops of wheat, corn and rice. Judging from the Fertilization Coefficient, more than 60 percent of farms are using fertilizer with amounts no more than 50 percent deviating the average amounts with certain fertilizing regions.

Perceptions of proper fertilization are held by some farmers, including applying fertilizer by instructions, recycling the packages collectively, concerning on the possible crop lodging and soil compaction due to over fertilization. Simultaneously, traditional conceptions still affect many farmers, such as the over emphasized production effects and private experiences, reusing the packages for food-storage, etc.

According to the empirical analyses, sowing area and ratio of migrant income is positive, while annual income is negative for appropriate fertilization. As to the odds of using organic fertilizer, no significant effects detected from chemical fertilizer application and breeding of livestock and poultry, while cash income and age of householders are positive, location in the north, sowing scale, ratio of grain crops and migrant income are measured as negative.

6.4.2 Policy recommendations

(1) As shown above, the fertilizing elements are not well balanced, and amounts of fertilizer used in many farms deviate much from the moderate levels. Therefore, it is an urgent task for the government to provide prompt, accurate and convenient soil testing techniques, and recommend referential standardized fertilizing amounts to farmers with different land properties and planting structures (F. Zhang, *et al* 2008).

(2) Enlarging the managerial scales of agriculture. As analyzed above, larger scale is positive to maintain appropriate fertilizing amounts. Managerial scales of the farms can be expanded either through the concentration of land on farms' own willing, or joining into the Specialized Farmers' Cooperatives as demonstrated by Q. Sun (2008), H. Dai (2010).

(3) Promoting migrant employment of rural labors, as ratio of migrant income is positive to appropriate use of fertilization and application of organic fertilizer. To accelerating the transfer of surplus labors from agriculture to the other sectors, thus increase incomes of rural households, the main tasks include promoting the vocational training, perfecting the employment information networks, and protecting the legal rights of the migrant workers.

(4) Strengthening social education on scientific fertilization. This survey reveals that behaviors including fertilizing by private practices, misusing the used packages, etc, still exist amongst many farmers, and their perceptions on safe application of fertilizer need to be improved. Hence educations on appropriate amounts of fertilizer, balancing the elements, proper recycling the used packages, etc., are in high necessary of to be strengthened (C. Yin, *et al* 2010).

6.4.3 Open research topics

In farms' use of fertilizer, there are still some points open for further studies, e.g., reasons behind impacts of the farms' location in the north or south, gender of the householders, etc. In future researches, inclusion of these contents in the questionnaire, will benefit further interpretations. Moreover, additional questions can be included, such as the determinants out of the farms like the price changes of fertilizer, motivation for using organic fertilizer, etc., hence are referential for policy recommending.

Chapter 7 Farmers' Application of Pesticides from Six Eastern Provincial-level Regions

7.1 Introduction

In the latest decades, with the steady increase of agricultural production in China, pesticides have been used extensively to increase crop yields and produce high quality products (J. Zhou, *et al* 2009). Until end of 2010, the total amount of chemical pesticides produced in China has amounted to 2.34 million tons, maintained an average annual growth rate of 10.32 percent since 1985 (CNSB, 2011). China has become the largest producer, user, and exporter of pesticides in the world (Q. Wei, *et al* 2011). Meanwhile, the improper use of pesticides has become a major source of food safety incidents, which have resulted in serious threats and losses on ecological environment, human health and economic development. Therefore, safe application of pesticides is drawing unprecedented public concerns, and Chinese government is strengthening regulations on the production, marketing and use of pesticides (X. Song, 2011).

As household farms are the overwhelming managerial units in Chinese agriculture, many scholars tried to accelerate the safe application of pesticides through understanding behaviors and determinants of the farmers. A brief literature review shows that, there are still a variety of topics needs to be researched with further depth. (1) In terms of the survey areas, H. Wang, *et al* (2004) surveyed 204 farms in Dongtai County, Jiangsu Province; H. Li *et al* (2007) surveyed 214 farms of Guanghan Prefecture, Sichuan Province; Y. Zhu, *et al* (2010) sampled 160 farms from 4 villages in Anji County, Zhejiang Province. If more farms from a larger scope of regions be sampled, the findings and conclusions will be more representative to capture important information on pesticides application. (2) Some scholars oriented their studies to the pesticides application on a certain type of agricultural product, including rice (H. Wang, *et al* 2004), apple (Q. Sun 2008), vegetables (J. Zhao, *et al* 2007; J. Zhou, *et al* 2009), etc. However, most of the farms are growing several agricultural products, on which the pesticide applications are affecting each other, due to limited household budgets, personal preferences, etc. Therefore, inclusion of all the major products grown in a farm will benefit the understanding of their behaviors and determinants of pesticide application. (3) From perspective of the determinants, G. Li, *et al* (2007) explored impacts from the certification of pollution-free agricultural products; Y. Zhu, *et al* (2010) compared different types, doses and frequencies of pesticides applied in farms with different scales. As farmers' behaviors are affected by a variety of factors, much comprehensive indicator systems are necessary to specify their natural and social characteristics. (4) In respect to the measurement of the application behaviors, some scholars used the monetary expenses on pesticides (G. Li, *et al* 2007), while in some other studies, the behaviors are represented by the characteristics as toxic or environmentally friendly (Y. Zhang, *et al* 2004), whether highly toxic pesticides are used (J. Zhao, *et al* 2007), willingness of applying safe pesticides (H. Li, *et al* 2007), etc. However, analyses based on physical amount of pesticides, which determines the pesticidal effects in the first place, will provide a better scenario of farmers' behaviors. Furthermore, the integrated analyses on the determinants of farmers' application of chemical pesticides, including the toxic pesticides, and the implementation of biological control methods, etc., will be much beneficial for policy recommending.

Therefore, this study is based on the survey to 560 household farms of eastern China's 6 provincial-level regions, as introduced in Chapter 6 (Appendix II). The remainder of the chapter is organized as follows: Section 2 briefly describes the field survey and basic statistical summaries; Sections 3 and 4 analyze determinants on farmers' behaviors towards pesticide application; in Section 5, conclusions and policy recommendations are presented, followed by open research topics.

7.2 The field survey

7.2.1 Theoretical model

To analyze farmers' application of pesticides (F_p), drawing upon the rural household models of W. E. Huffman (2001) in Eq.6-1 to Eq.6-4, production decision on a certain variable input (X), four types of variables are included to depict major constraints of household farms in the same model as formulated in Chapter 6:

$$F_p = F\ (HR, LC, HI, GL) \tag{7-1}$$

As household is the most important member in decision-making, the category of human resources (HR) consists of variables on age, gender and education level (E) of the households. As the production function Eq.6-2 permits adopting new inputs (W. E. Huffman, 2001) and land in the basic means in agro-production, two variables on land cultivation (LC) are adopted. In the variables on household incomes (HI), total cash income constraint (I) is represented by annual cash incomes, while off-farm wage work H_m is described with the ratio of migrant incomes. Finally, as geographic location (GL) affects the technology and agro-climatic conditions (A), market wage of the off-farm work (W_m) and prices of the inputs (W_X), two variables are included to show farms' affiliation to the metropolises, and location in the north or south,. Variables in each type and the modeling mechanism are shown in Fig.7-1.

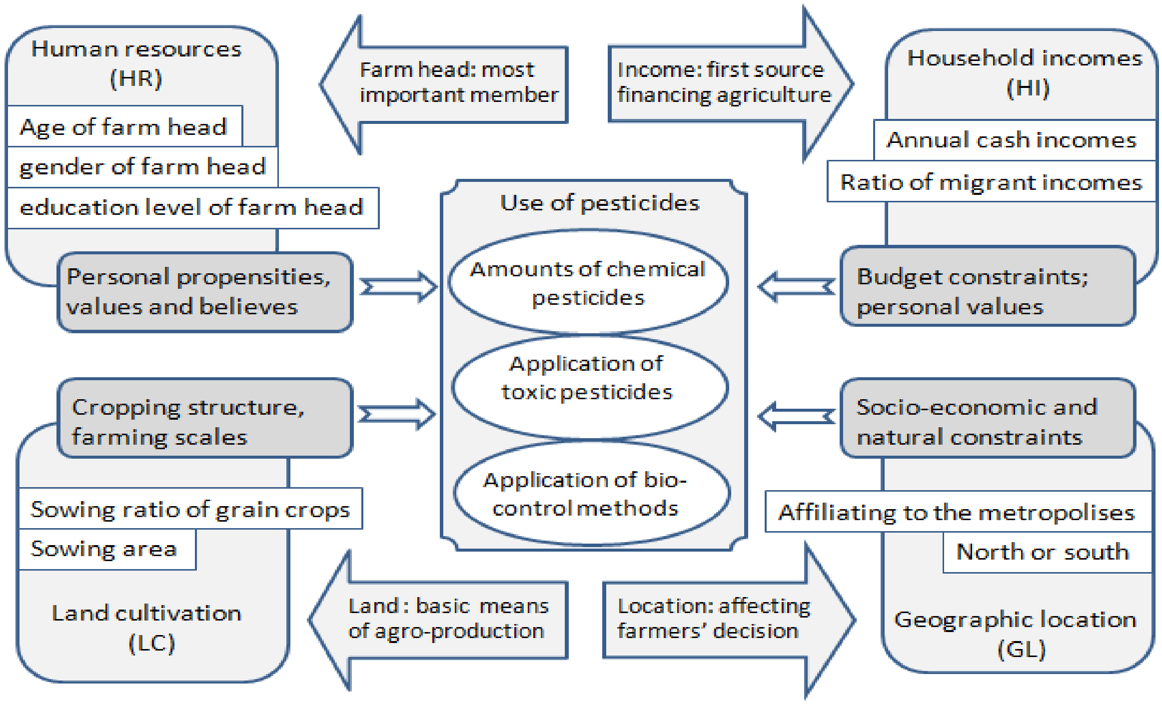

Fig. 7-1 Mechanism of modeling farmers' use of pesticides

7.2.2 Demographic characteristics

In terms of the analysis about pesticide application, similar with some previous studies (Y. Zhang, *et al* 2004), only farms answered as used pesticides in 2010 are included in this chapter. From this survey, a total sample sized of 220 valid responses is used in this study. We include 9 indicators to represent the demographic characteristics of each farm (Table 7-1). In the following sections, these indicators will be used as candidate determinants to interpret farmers' behaviors.

(1) Due to the key role of householder in making productive decisions within a family farm, many studies included relevant variables in the analysis of safe agricultural production. In this study, we include three variables to describe characteristics of the householders, i.e., human resources (*HR*), as *gender* (Q. Song, *et al* 2010), *age* (H. Li, *et al* 2007) and education level (*edu*, Y. Zhang, *et al* 2004). (2) At the same time, to model the impacts of land cultivation (*LC*) to safe agricultural production as Q. Song, *et al* (2010), two continuous variables are introduced: the sowing area of total agricultural products (*scale*), rather than total area of farmland is adopted with the consideration of multiple cropping (H. Wang, *et al* 2004); sowing ratio of grain crops (*grainr*) is included to identify the significance of land use structure. (3) Meanwhile, another two variables are used to measure the impacts of discrepancies in household income (*HI*): total annual cash

income (*income*) affects household budget and thus the inputs to agricultural production, including those on pesticides and spaying apparatuses (G. Li, *et al* 2007; Y. Zhu, *et al* 2010); ratio of income from migrant job (*mir*) shows the main sourcing structure of family income, which affects the relative importance of agriculture and the inputs (H. Dai, 2010). (4) Finally, two dichotomous dummy variables are incorporated to show the importance of geographic location (*GL*) as Y. Zhang, *et al* (2004), with *north* equal to 1 if a farm is from Beijing, Hebei or Shandong, and *metro* coded as 0 for farms locating in neither Beijing nor Shanghai. The statistical summary of each variable is shown in Table 7-1.

Table 7-1 Demographic characteristics of the sampled farms applied pesticides

Characteristic	Type [a]	Unit	N	Mean	Min	Max	Std. D.	C.V.
Age of farm head (*age*)	HR	year	211	49.68	26.00	78.00	10.08	0.20
Sowing area (*scale*)	LC	*mu* [b]	220	5.95	0.50	38.00	4.82	0.81
Ratio of grains sowing scale (*grainr*)	LC	%	217	39.20	0.00	100.00	35.40	0.90
Ratio of migrant income (*mir*) [c]	HI	%	216	37.76	0.00	100.00	41.59	1.10
Gender of farm head (*gender*)	HR	dummy	211	1=male (204 [d]); 0=female (7)				
Education level of farm head (*edu*)	HR	dummy	208	1=illiteracy (8); 2=primary (49); 3=middle (106); 4=high (40); 5=advanced (5)				
Total cash income in 2010 (*income*)	HI	dummy	218	1=under 10000 *yuan* (16); 2=10000-30000 *yuan* (86); 3=30000-50000 *yuan* (82); 4=over 50000 *yuan* (34)				
North or south of China (*north*)	GL	dummy	220	1=north (129); 0 =south (91)				
Metropolises or not (*metro*)	GL	dummy	220	1= Beijing or Shanghai (55); 0= the other regions (165)				

Note: [a] referring to the four types of variables shown in Fig.7-1; [b] as a main unit of land measurement in China, 1 *mu*=666.67m^2; [c] the income sources contain migrant jobs and sales of agricultural products; [d] the bracketed numerals denote counts of farms.

Source: field survey by the authors

7.2.3 Behaviors on pesticide application

To capture the major behaviors of pesticide application in a farm, three aspects are included in our questionnaire. As usually a variety of pesticides, with different pest-control and environmental effects, are used in a farm, weights of pesticides applied in each agricultural product are summed to constitute the total amounts. Meanwhile, as the control of toxic pesticides and promotion of biological pest-controls are of great importance for safe agricultural production, relevant characteristics are included as well. The toxic pesticides incorporate Methamidophos, Furadan (Carbofuran) and Folimat (W. Zhang, 2008). According to the No. 199 Bulletin of China Agricultural Ministry (2002), Methamidophos is prohibited to be applied in agriculture, and Furadan cannot be used on vegetables, fruiters, tea and medicinal herbs. As another major toxic pesticide, Folimat has been banned in some regions including Zhejiang (K. Tao, *et al* 2005), Jiangsu (SCSC, 2007), etc.

Table 7-2 Application of pesticides in the sampled farms

	Unit	N	Mean	Min	Max	Std. D.	C.V.
Total amount	*kg/mu*	220	1.05	0.01	11.67	1.92	1.82
Toxic pesticides	*kg/mu*	105	0.51	0.01	7.27	1.25	2.43
Methamidophos	*kg/mu*	47	0.37	0.01	3.33	0.59	1.59
Furadan	*kg/mu*	14	3.74	0.33	13.33	3.88	1.04
Folimat	*kg/mu*	62	0.53	0.00	5.00	1.05	1.98
Bio-control of total farms	dummy	306	1= implemented (46); 0= unimplemented (260)				
Bio-control of farms used pesticides	dummy	168	1= implemented (32); 0= unimplemented (136)				

Note: the bracketed numerals denote counts of farms.

Source: field survey by the authors

The bio-control methods of pests in agriculture are measures to eliminate insects, mites, weeds and plant diseases, etc., relying on certain biological mechanisms of secretion, smell, predation, parasitism, herbivory, etc., thus reduce the use of chemical pesticides. For example, using the smell of onions to kill germs causing black spike of wheat, intercropping beans in corn field to attract beneficial insects and prey upon pests, raising ducks and fish in rice fields to control weeds, etc (W. Zhou, *et al* 2009). Application of pesticides and bio-control measures in the sampled farms are shown in Table 7-2.

The agricultural products we surveyed include wheat, corn, rice, cotton, oilseed, soy and fruits, and application of pesticides per *mu* of each product is presented in Table 7-3. The average pesticides used in the three main grain crops of wheat, corn and rice is 0.51

kg per *mu*, which is much less than that of the other products as 1.79 *kg* per *mu*. Meanwhile, judging from the coefficient of variance (C.V.), amounts of pesticides used in these main grain crops are much discrepant than that of the other products. According to the survey, toxic pesticides are used in all the products except for fruiters, amongst which Methamidophos is used in rice and soy, Folimat is used in wheat, cotton, cole and cotton, while Furadan is used in cotton. Finally, bio-control methods are used in much fewer farms, and coving most of the products other than cotton and soy.

Table 7-3 Application of pesticides in each agricultural product

	Application of chemical pesticides							Number of farms used	
	Unit	N	Mean	Min	Max	Std. D.	C.V.	Toxic pesticides	Bio-control
Wheat	*kg/mu*	95	0.37	0.01	3.00	0.56	1.53	48	9
Corn	*kg/mu*	48	0.23	0.02	1.25	0.27	1.21	32	6
Rice	*kg/mu*	46	1.09	0.02	5.00	1.31	1.20	15	2
Cotton	*kg/mu*	28	1.44	0.02	6.00	1.69	1.17	17	0
Fruiter	*kg/mu*	26	5.29	0.40	11.67	2.50	0.47	0	27
Oilseed	*kg/mu*	34	0.58	0.15	2.13	0.43	0.75	33	4
Soy	*kg/mu*	27	0.32	0.10	0.50	0.09	0.28	26	0

Source: field survey by the authors

7.2.4 Perceptions on pesticide application

Within this questionnaire, 5 questions are concerning farmers' perceptions on pesticide application, from choosing and field application to the withdrawal periods, and the possible consequences of overdosing. Moreover, as pesticides containers may be toxic and improper disposal may menace environmental safety and human health (H. Li, *et al* 2007), another question is adopted in this topic. For each question, the number of valid responses, counts of responses and the corresponding percents to each choice are shown in Table 7-4.

It shows that for most of the farmers, productive effects are the most determining factors in choosing and using pesticides, less attention is paid upon the environmental effects and sprayers' health. When determine the doses, almost 50 percent farmers are answering as following container instructions, while some one third of them are relying on their own experiences. Although more than 80 percent farmers have heard of the withdrawal period of pesticides, the well known ratio is less than 20 percent. In the disposal of pesticide containers, almost 40 percent farmers answered as littering, thus threat the environment and human health. On the possible consequences of overdosing, negative effects on sprayers' health, food safety and environment are recognized by more than half of the respondents simultaneously. Hereby the coexistence of the proper and traditional perceptions is shown amongst the farmers.

7.3 Analysis on the behavior determinants

7.3.1 On the total amount of pesticides

In the prior studies, multivariate OLS regression models are used to identify the significant determinants of pesticide application, as H. Wang, *et al* (2004), G. Li, *et al* (2007), etc. In this study, the model used to find the important factors of total chemical pesticides amount is formulated as:

$$Y=\beta_0+BX+u \tag{7-2}$$

where Y is the total amount of pesticides applied per *mu*, $X=(x_1, x_2, \ldots, x_9)^T$ is a vector contains the 9 variables listed in Table 7-1, β_0 and $B=(\beta_1, \beta_2, \ldots, \beta_9)$ are coefficients need to be estimated, while u is the random error.

Table 7-4 Statistics of the significant determinants on total pesticides used per *mu*

Variables	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Error	Beta		
(Constant)	0.107	0.493		0.217	0.829
Metropolis or not (*metro*)	2.355^{***}	0.219	0.605	10.747	0.000
Gender of farm head (*gender*)	0.846^{*}	0.481	0.099	1.759	0.080
Income ratio of migrant job (*mir*)	-0.004^{**}	0.002	-0.109	-1.975	0.050
Ratio of grain sowing scale (*grainr*)	-0.010^{***}	0.003	-0.222	-3.996	0.000
Valid N=199; F =33.13, Sig=0.000^{***}; R^2=0.406					

Note: Dependent Variable: pesticides used per *mu*; ***, **and *represent statistical significance in the level of 1%, 5% and 10%, respectively.

Software: SPSS 13.0

Table 7-5 Perceptions concerning pesticide application

1. Determinants on choosing of pesticides (Single-choice with 546 valid responses)					
Price	Productive effects	The sellers	Peer practices	Follow-up services	Environmental effect
103 (18.86%) [a]	380 (69.60%)	16 (2.93%)	31 (5.68%)	1 (0.18%)	15 (2.75%)
2. Determinants of using pesticides (Single-choice with 546 valid responses)					
Costs	Productive effect	Environmental effect	Sprayers’ health	Quality of agro-product	
120 (21.98%)	343 (62.82%)	13 (2.38%)	7 (1.28%)	63 (11.54%)	
3. Determinants of pesticides dose (Single-choice with 546 valid responses)					
Container instructions	Private experience	Instruction from the extension staff	Peer practices		
278 (50.92%)	191 (34.98%)	42 (7.69%)	35 (6.41%)		
4. Withdrawal period of pesticides (Single-choice with 557 valid responses)					
Knows very well	Knows fairly well	Knows a little	Unknown		
97 (17.41%)	248 (44.5%)	105 (18.85%)	107 (19.21%)		
5. Disposal of the pesticide containers (Single-choice with 550 valid responses)					
Individual recycling	Burning up	Littering	Collective recycling	Others	
79 (14.36%)	73 (13.27%)	212 (38.55%)	182 (33.09%)	4 (0.73%)	
6. Consequences from overdosing of pesticides (Multiple-choice with 557 valid responses)					
Imperiling sprayers’ health	Imperiling food security	Pollution	Effective pests controlling	Unknown	Others
337 (60.50%)	423 (75.94%)	316 (56.73%)	105 (18.85%)	16 (2.87%)	9 (1.62%)

[a] Note: numerals are the counts of valid farm, and the bracketed numbers are the corresponding percents of farms.

Source: field survey by the authors

Through the multivariate linear regression process, with the independent variable selection method of Backward in the statistical software of SPSS 13.0, four significant determinants are chosen in the final model. Concerning statistics of the model are shown in Table 7-5. The significant values of F and t (p-value < 0.1) indicate a good fitness of this model[1].

The results show that, farms affiliating to the two metropolises of Beijing and Shanghai (*metro*=1), or headed by males (*gender*=1) are positive, while ratios of income from migrant jobs (*mir*) and grains sowing scales (*grainr*) are negative with the amount of chemical pesticides applied per *mu*. (1) The coefficient of *metro* can be explained by the comparison of average pesticides used per *mu* and other indicators of the farms. Within the 199 farms included in this model, farms affiliating to the metropolises applied 2.64 *kg* of pesticides per *mu* with the sowing area of 3.84 *mu* in average, while the corresponding indicators in non-metropolises farm are 0.38 *kg* per *mu* and 6.70 *mu* respectively, thus the formers may have to maintain high yields through more application of pesticides. Simultaneously, the higher annual cash incomes in farms affiliating to the metropolises[2] enable them to input more in pesticides. However, we should notice that this discrepancy may threat the environmental and food safety of the metropolises. (2) As to the finding that male headed farms are applying more pesticides, it indicates that males are more concerning about the productive effects of farming activities and suitable to spray large volume of pesticides in physical power, as investigated by H. Li, *et al* (2007). (3) The negative effect of income ratio of migrant job is in line with G. Li, *et al* (2007). The more non-agricultural income usually result in less farming time and attention in agricultural yields, thus the application of pesticides may be decreased. (4) As analyzed above, the three types of staple grain crops are supplied with less pesticide than the other agricultural products. Therefore, their sowing ratio goes negatively with the total amount of pesticides.

7.3.2 On the toxic pesticide application

To model factors significant for application of the toxic pesticides defined above, the

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[1] Although a not very high R^2 value of 0.406 is given in the table, it should not be used to judge the fitness of a model. The fact that R^2 never decreases when any variable is added to a regression makes it a poor tool for deciding whether one or several variables should be added to a model. Low R^2s in regression equations are not uncommon, especially for cross-sectional analysis. Thus using R^2 as the main gauge of success for an econometric analysis can lead to trouble (J. M. Wooldridge, 2003).

[2] Using the codes of 1, 2, 3, 4 to denote the ascending income levels of Table 1, within the 199 farms included in this model, the mean in farms affiliating to the metropolises is 3.02, while that in the other farms is 2.48.

dependent variable is a dichotomous indicator being coded 1 if applied and 0 if not. As the OLS modes like Eq.7-3 is inappropriate for discrete and limited dependent variables (J. Jack, *et al* 1997), a Binary Logit Regression model is adopted (J. Zhao, *et al* 2007; H. Dai 2010) and defined as (H. R. Seddighi, *et al* 2000):

$$Log\left[\frac{P(Y_1)}{P(Y_0)}\right] = \beta_0 + \sum_{i=1}^{9} \beta_i x_i + \varepsilon \tag{7-3}$$

where Y is the application of toxic pesticides with $P(Y_1)$ denotes the probability of being applied, while $P(Y_0)$ means that of being unapplied; x_i (i=1, 2, …, 9) are the 9 variables listed in Table 7-1; β_0 and β_i (i=1, 2, …, 9) are coefficients need to be estimated; ε is the random error.

Estimation of this model is carried out through application of the Binary Logistic Regression procedure in SPSS 13.0. The Backward approach is adopted to remove the statistically insignificant variables (p-value≥0.1), from the initial model with all the candidate determinants as independent variables. The final model includes four predictors, all of which embrace p-values less than 0.01 (Table 7-6). The column B estimates log-odds coefficients of β_i in Eq.7-3, for predicting the dependent variable by the independent variables. The last column lists the exponentiation of B, the ratio of $P(Y_1)$ and $P(Y_0)$, thus be called *odds ratios* simultaneously. In this case, an *odds ratio* over 1 denotes that the toxic pesticides are more probably be used, while an *odds ratio* less than 1 implies that the toxic pesticides are easier not be used (J. Bruin, 2006).

Within the four significant variables listed in Table 7-6, *mir* is positive to the odds of toxic pesticides be applied, while the other three variables are negative with the application probability of toxic pesticides in a farm. (1) Being the Capital and largest city in China, respectively, especially thanks to the hosting of Olympic Games and World Expo, Beijing and Shanghai have adopted stringent regulations to prevent using of highly toxic pesticides (X. Song, *et al* 2008; X. Bo, 2009). Therefore, the less probability of applying toxic pesticides there, hence the negative effect of *metro* can be interpreted. (2) For a farmer, the more income from migrant jobs means less time and attention for farming in general. However, due to the instable conditions and high living expenditure outside of homeland, most of the migrant farmers have to leave their families at home and engage in agriculture (Y. Zhang, *et al* 2004). As most of the left family members are women, children, and the elderly, they are prone to control the pests through the more efficient toxic pesticides. The positive effect of *mir* may reveals that the more they get from migrant jobs, the more they will be afford to buy and use the toxic pesticides. (3) However, when observe farms' cash *income* with units of dozens of thousand yuan as shown in Table 7-1, farms with upper level of income are tend to use less toxic pesticides as their major income come from non-agricultural sectors[1]. Through the tradeoff with the probable efficient pest-control by toxic pesticides, most of them may prefer to conserve the environment and food security. (4) Finally, as the three types of staple grain crops need less pesticide in general, the application of toxic pesticides is negative with the *grainr* simultaneously.

Table 7-6 Binary logistic regression on whether toxic pesticides used

Variables	B	S.E.	Wald	df	Sig.	*odds ratio*
Metropolis or not (*metro*)	-2.507***	0.607	17.051	1	0.000	0.082
Income ratio of migrant job (*mir*)	0.018***	0.005	11.975	1	0.001	1.081
Total cash income in 2010 (*income*)	-0.755***	0.251	9.019	1	0.003	0.470
Ratio of grain sowing scale (*grainr*)	-0.027***	0.006	18.828	1	0.000	0.974
(Constant)	2.515	0.640	15.458	1	0.000	12.363

Cases included in analysis: 199; Missing cases: 21; Total cases selected: 220

Dependent variable: whether toxic pesticides are used, with 93 cases = 1, and 106 cases = 0

Omnibus tests of model coefficients: *Chi*-square (4)=71.642, Sig.=0.000***

Note: *** represents statistical significance in the level of 1%.

Software: SPSS 13.0

7.3.3 On the adoption of biological pest-controls

With the same Binary Logistic Regression procedure in SPSS 13.0 and the 9 variables as the candidate determinants, we measure the significant factors for the implementation of biological pest-control in the sampled farms.

As shown in Table 7-7, through the predictor selection method of Backward, three variables are included in the final model. Judging from the *odds ratio* of each variable, (1) farms from the north (*north*=1) or (2) affiliating to the two metropolises (*metro*=1) are more probably to adopt biological measures. Within the 46 farms answered as conducted biological pest-controls, 36 are from the north and 31 are from the two metropolises, the ratios are 78.26 percent and 67.39 percent, respectively. To the positive significance of *metro*, it may because that as aforementioned, being the Capital and largest city in China respectively, Beijing and Shanghai are taking full use of their solid industrial foundation and advantages in technology, trade, information, making greater efforts to promote the research and production of low toxicity and environmentally

[1] Within the 199 farms included in this model, no migrant income occurred in the farms with annual cash income less than 10000 *yuan*, while this ratio in the other three income levels of Table 1 are 22.70%, 54.58% and 60.56%, respectively.

friendly pesticides (D. Gu, 2004; W. Zhou, *et al* 2009). As to the difference between the north and south, further investigations are necessary to explore the possible reasons in cropping structure, farming habits, the degree of pest damages, etc. (Y. Zhang, *et al* 2004), hence searching for suitable countermeasures to extend biological pest-controls in different regions. Meanwhile, (3) income ratio of migrant job (*mir*) is found negative with the introduction of biological pest-controls. It may be because that farms lying more on the non-agricultural incomes, usually have less time and attention to farming, much less controlling pests through biological methods.

Table 7-7 Binary logistic regression on implementation of biological pest-control

Variables	B	S.E.	Wald	df	Sig.	*odds ratio*
North or south of China (*north*)	0.980**	0.572	2.929	1	0.087	2.664
Metropolis or not (*metro*)	3.403***	0.571	35.490	1	0.000	30.056
Income ratio of migrant job (*mir*)	-0.011	0.007	2.574	1	0.109	0.989
(Constant)	-3.239	0.570	32.273	1	0.000	0.039

Cases included in analysis: 274; Missing cases: 286; Total cases selected: 560

Dependent variable: whether biological pest-controls are implemented, with 27 cases = 1, and 247 cases = 0

Omnibus tests of model coefficients: *Chi*-square (3)=47.607, Sig.=0.000***

Note: ***, ** and * represent statistical significance in the level of 1%, 5% and 10%, respectively.

Software: SPSS 13.0

7.4 Conclusions and Recommendations

7.4.1 Major conclusions

The survey shows that pesticides used in the three staple grain crops are less than that of the other products, but more discrepant amongst the farms. The toxic pesticides are applied in most of the products and some 50 percent of the sampled farms, while bio-control methods are used in only about one sixth of the farms. Perceptions on proper application of pesticides exist amongst some of the farmers, including applying by instructions on the containers, awareness on the withdrawal periods, collective recycling of the containers, concerning upon sprayers' health and food security. Simultaneously, traditional conceptions still influence many of them, such as the over emphasized importance of productive effects and private experiences, littering the pesticide containers, etc.

According to the empirical analyses, farms in the two metropolises and headed by males are positive, while ratios of income from migrant jobs and grains sowing scales are negative with the amounts of pesticides applied. With respect to the application probability of toxic pesticides, income ratio of migrant job is positive, while the other 3 variables of *metro*, *income* and *grainr* embrace negative effects. Farms' location of whether north or affiliating to the metropolises are measured as positive, while ratio of migrant income is negative to the odds of adopting biological pest-controls.

7.4.2 Policy recommendations

(1) Extending advanced techniques to improve pesticidal efficiency and guarantee safe application of pesticides. In addition to the alternative techniques and products of toxic pesticides, biological pest-controlling techniques, techniques on efficient pesticide spraying, monitoring the residues, decomposing garbage including pesticides containers, etc., are being highly needed by the farmers.

(2) Severe inspection on the production, circulation and use of highly toxic pesticides, including the improvement of the licensing, registration and classification systems of pesticide production, establishing the tracing back systems and cracking down the illegal production and trafficking of highly toxic pesticides.

(3) According to the foregoing analysis, ratio of migrant income is negative to amount of pesticides; total income is negative to use of toxic pesticides. Therefore, continuing transfer of surplus labors from agriculture to the other sectors is still necessary, which can improve the total income of rural households simultaneously. The main tasks include promoting the vocational training, perfecting the employment information networks, and protecting the legal rights of migrant workers.

(4) This survey reveals that behaviors like littering the containers, spraying pesticides by private practice still exist amongst many farmers, and their perceptions on safe application of pesticides need to be improved. Hence education on scientific application of pesticides, which is poor in traditional education, is in high necessary to be strengthened (Q. Wei, *et al* 2011).

7.4.3 Open research topics

In terms of pesticide application amongst the sampled farms, there are still some relationships not being well interpreted, e.g., why farms from the north are much easier to adopt biological pest-controls? Moreover, much more questions can be included, such as the determinants out of the farms like the price changes of pesticide, motivation for using toxic pesticides and biological pest-controls, pesticide-related technologies in most needs, etc., hence are referential for policy recommending.

Chapter 8 Conclusions and Recommendations

8.1 Review of the contents

As shown in Fig.1-3, three sections are included in this Doctoral thesis. As Section 1, Chapter 1 demonstrates the background of agricultural development in China. The main points include the necessary of sufficient and safe supply of agricultural products, due to the largest population of 1.37 billion; the significance of improving the efficiency of agricultural production with limited farmland, increasing fiscal inputs and transferring of surplus agro-labors; the urgency of study the application of fertilizer and pesticides, in the context of the dual impacts of agricultural chemicals of supported agro-growth in the first place), while menacing environmental and food safety simultaneously; the importance to understand behaviors and perceptions of household farms, which are the overwhelming productive units in China today. Subsequently, several study objectives are deduced, consisting of identifying the significant factors of agro-development in latest decades; measuring traits of production efficiency of both staple grain crops and individual farms; specifying the significant determinants affecting farms' production efficiency; capturing farmers' behaviors and perceptions of using fertilizer and pesticides, and the significant determinants.

Being the principal parts of this thesis, the Section 2 is composed by six chapters. Chapter 2 conducted a factor analysis of Chinese agriculture development, from the perspectives of inputs change, institutional transition and technological progress. The source of data is the time-series data after 1983 issued by the government, and the major model adopted is Cobb-Douglas production function. In Chapter 3 and 4, production efficiency of wheat and corn in Hebei Province are measured, with an input-oriented DEA model with the assumption of Variable Return to Scale (VRS). The data is gathered from the agricultural product survey conducted by the government in 2008, and different counties are treated as the Decision Making Units (DMUs). Furthermore, production efficiency in corn and wheat are compared with the adoption of Crosstabs Analysis. Using the similar DEA models, Chapter 5 develops a framework on agricultural production efficiency of individual farm. The data source is a survey to 99 household farms of Hebei province, China, conducted by the authors in 2010. In the second stage, effects of a variety of social and natural determinants are assessed, with the adoption of an Ordinal Logistic Regression model. In succession, Chapter 6 and 7 study farmers' application of fertilizer, including the total amounts, main components of fertilizer and pesticides, based on another survey to 560 household farms in six provincial regions of eastern China. Then, we summarize farmers' perceptions, ranging from choosing fertilizer and pesticides, field application, disposal of the used packages and awareness on the possible consequences of over use of agro-chemicals. Nine indicators are adopted as the predictors, including information on the householders, land-using and planting structure, household income and geographical location. Fertilization Coefficient is formulated to isolate effects of farms' geographical location and planting structure, hence capture farmers' propensities on fertilizing. Through the adoption of multivariate regression and binary logistic regression models, these chapters identify significant determinants behind behaviors of the farmers.

In this chapter serving as the final section, we intend to conclude the main contents and findings in the foregoing chapters, and bring forward the comprehensive policy recommendations.

8.2 Major conclusions

In Chapter 2, the application of chemical fertilizer is measured as the most important factor, following by technical progress, increased fixed assets and fiscal supports. Meanwhile, due to the negative elasticity of agro-labor number, increasing the number of agricultural labor results in negative contribution to Chinese agricultural development (D. Li, *et al* 2011b).

In Chapter 3 and 4, within the sampled counties treated as the Decision Making Units (DMUs), most of them are in the status of increasing returns to scale. Slack analysis of outputs shows that comparing with technical improvement, much more margin lies in the socio-economic optimization. Meanwhile, the liquid inputs are similar in the efficient and inefficient counties, with less slack and radial movements; large differences, slack and radial movements exist amongst inputs connecting with the construction of agricultural infrastructure. Furthermore, Crosstabs Analysis confirms the significantly relating returns to scale of wheat and corn, due to multiple cropping; significantly relating technical efficiencies and relating returns to scale within both wheat and corn, under the laws of crop growth and yields; corn is more efficient than wheat production, and increasing the farming scales is more important to the wheat, from the counts of DMUs (D. Li, *et al* 2011a, c).

According to the efficiency scores of DEA in Chapter 5, most of the inefficient farms can improve efficiency through enlarging their farming scales; ratios of net profit has a larger average slack to be increased than the absolute value; irrigation costs can be saved with the largest margin; large slacks exist in fertilizer and pesticides. The empirical analyses in the second stage indicate that farms with aged and male head are more efficient; increasing the numbers of agro-labor negatively affect production efficiency; the public services do not improve the efficiencies, unless conducted together with farms' efficient access to the credit (D. Li, *et al* 2012a).

With regard to the application of fertilizers revealed in Chapter 6, rich Nitrogen and poor Potash is verified through counts of the farms; less chemical fertilizers are used upon the three staple grain crops in average. Meanwhile, productive effects dominating farmers' choose and use of fertilizers; proper and traditional perceptions are coexisting, e.g., applying fertilizers by instructions, concerning on possible soil compaction due to over fertilization, while rinsing and reusing the packages for food-storage, etc. Empirical analysis indicates that sowing area and ratio of migrant incomes of a farm are positive with appropriate amounts of chemical fertilizers, while age of farm head and household income are positive with the use of organic fertilizer (D. Li, *et al* 2012b).

Finally, in the light of description of pesticides application among the farms in Chapter 7, toxic pesticides are widely used, while bio-control techniques need to be extended. Similar with fertilizers, productive effects dominating farmers' choose and use of pesticides; proper and traditional perceptions are coexisting, such as applying pesticides by instructions, knowledge on withdrawing period, concerning on risks of food security due to overdose of pesticides, while littering containers. Empirical analysis shows that farms affiliating to the metropolises are apt to use more non-toxic chemical pesticides and bio-controls; ratio of migrant income is negative with amounts of pesticides; higher ratio of grain crops reduces the odds of using more chemical pesticides (D. Li, *et al* 2012c).

8.3 Policy recommendations

In each chapter, Policy recommendations have been raised in responding to the respective conclusions. Being the last section of this thesis, it is necessary to integrate the individual recommendation on the basis of main conclusions of each chapter as shown in Fig.1-3, and analyze further with examination of current status and concerning literature.

8.3.1 Enlarging the managerial scales of agriculture

In the DEA analyses on production efficiency, most of the DMUs are in the status of increasing returns to scale, and size of farmland sampled is demonstrated as not large enough for generating scale economy. Sowing area is measured as positive with appropriate use of chemical fertilizers, while negative with amounts of pesticides.

Being the major measurement of farming scale, farmland size should be increased through accelerating the circulation and concentration of land-use right among farms. In

China, as land is performing as self insurance of subsistence, farmland should be concentrated according to the *Law of the People's Republic of China on the Contracting of Rural Land* (enacted since Mar. 1st, 2003) and *Regulations on the Circulation of Rural Land Contracted Management Right* (No.47 Order of the Ministry of Agriculture, enacted since Mar. 1st, 2005), following the principles of legality, equality, voluntariness and making compensations.

According to the studies of C. Wang (2011), Y. Cao (2011), etc, although farmland-use right is transferred in many farms, they usually occur among relatives with small scales, short terms and informal procedures, thus the tenants have enthusiasm to inputting more upon the farmland and improve production efficiency. To tackle with these problems, on one hand, urban-rural social insurance systems, including health insurance, pension security, etc, should be further extended, hence reduce farmers' reliance on the farmland (H. Xu, *et al* 2011). On the other hand, employment opportunities and non-agricultural sources of income need to be increased, though the development of non-agricultural industries, thereby providing material basis for the land transfer. In addition, since the farmers cooperatives are developing quickly in latest year, especially after the execution of the Law on Specialized Farmers' Cooperatives in 2007, the cooperatives should be guided and encouraged to support corn production, including the purchase of capital goods, product marketing, credit accessing, etc (Y. Liu, 2011).

8.3.2 Improving the contribution of agro-technologies

Within the significant factors supported Chinese agricultural development accessed in Chapter 2, technological progress is demonstrated as in the second place. Meanwhile, agricultural chemicals are demonstrated as with large ratios of slacks and thus saving margins in DEA analysis, and the elementary substances are not well balanced, and the amounts in many farms deviate much from the moderate levels.

Therefore, it is an urgent task for the government to provide prompt, accurate and convenient soil testing techniques, and recommend referential standardized amounts of fertilizers and pesticides to farmers, with different land properties and planting structures (F. Zhang, *et al* 2008). In addition to the alternative techniques and products of toxic pesticides, biological pest-controlling techniques, techniques on efficient pesticide spraying, monitoring the residues, decomposing garbage including pesticides containers, etc., are being highly needed by the farmers.

In China, the five-level agricultural extension system has been serving as the main force in supporting agricultural development with advanced sciences and technologies. At present, obligations of these extension agencies mainly include four aspects: (1) judicial enforcement and executive administration, such as animal and plant quarantine, products inspection; (2) causes for public interests, such as monitoring the pests and diseases, training the farmers, consulting, introduction of new technologies, testing demonstration and extension of pesticides, animal drugs, soil fertility monitoring, etc; (3) intermediary undertakings, such as conveying production and marketing information to farmers, verifying farmers' professional skills, etc; (4) profit-making service, such as the vending of agricultural production materials, storage, transportation and marketing agricultural products, and so on. According to the *Law of the P.R.C. on the Popularization of Agricultural Technology* enacted since 1993, public welfare causes should be the central obligation of the agencies. Nevertheless, some surveys revealed that more than half of the staffs are engaging in affairs of the other three aspects as mentioned above (L. Duan, 2011). To resolve this problem, fiscal expenditure on agricultural extension needs to be increased[1] in the first place. Simultaneously, it is necessary to conduct severe supervision on these agencies to insure that they are functioning following concerning laws and regulations (K. Jia, 2010).

Meanwhile, relevant research institutes, colleges and universities, enterprises and social organizations are the indispensable supplements for agricultural extension. Favorite policies are needed to encourage these institutions engage more on extending appropriate agricultural technologies, such as subsides on concerning research projects, taxation and crediting preferences on field extension of high-tech products, etc.

Last but not least, farmers' qualities of acquiring and wielding of high agro-tech should be improved, through special training programs, cyber-resources and courses in both common middle schools and vocational education agencies.

8.3.3 Promoting migrant employment of rural labors

In line with the existence of surplus labor in rural China, agro-labor number is measured as with negative elasticity to agricultural output with Cobb-Douglas production function. Similarly, the increasing of agro-labor is demonstrated as negative to farms' production efficiency with DEA; ratio of migrant incomes is measured as positive with the appropriate amounts of chemical fertilizers, and negative with over use of pesticides. Moreover, as demonstrated by C. Wang (2011), migrant employment is significantly contributing the increase of farmers' income.

In China, the labors with rural household registration but engaging in non-agricultural works more than 6 months in a year are defined as Farmer Labors.

[1] The average public expenditure for agricultural extension accounts for 0.6% to 1% of the gross agriculture output in developed countries, and it accounts for some 0.5% in developing countries. However, the share is only 0.2% in China, and the annual extension funds for each staff is only about 1400-2000 yuan in average (J. Zheng, 2011).

With them, the ones working outside of their county-level registration areas are so-called Migrant Farmer Labors. In 2009, the total number of Farmer Labors amounted to 229.78 million, accounting for 28.79 percent of the national total employed labors. Meanwhile, the Migrant Farmer Labors were 145.33 million, accounting for 63.25 percent in total Farmer Labors [1]. According to the same bulletin, 51.1 percent of the Migrant Farmer Labors did not accept any forms of professional training; most Migrant Farmer Labors engaged in manufacturing (39.1 percent), following by construction (17.3 percent), other services (11.8 percent), hotels and catering services (7.8 percent), wholesale and retail trades (7.8 percent), transport, storage and post (5.9 percent); 93.6 percent of the Migrant Farmer Labors were being employed, while only 6.4 percent self-employed; 89.8 percent of the employed labors worked more than 44 hours each week, the legislative upper limit; only 42.8 percent of the employed labors covenanted contracts with the employers; only 7.6 percent, 21.8 percent, 12.2 percent, 3.9 percent and 2.3 percent of the employers paid pension insurance, injury insurance, medical insurance, unemployment insurance and maternity insurance for Migrant Farmer Labors.

Promoting migrant employment of agricultural labors, further endeavors are necessary to strengthen the non-agricultural vocational training of rural labors by the *Sunshine Project*, accelerating the reform of the family registration system, so as to shift surplus labors to both urban areas and local non-agricultural sectors. At the same time, the government needs to perfect the construction of employment information networks, and protect the legal rights of migrant labors (H. Zheng, 2011).

8.3.4 Channeling more fiscal and social funds to agriculture

In the light of analysis with Cobb-Douglas production function, fiscal agro-supporting funds supported agricultural development significantly. Moreover, access to credit is detected as one of the determinants to efficient production of individual farms.

The successful innovations of agricultural institutions commenced in late 1970s brought about unprecedented high-speed growth of monetary values and physical outputs in agriculture, hence constituted foundation for the all-round Reforms and Opening-up of the national economy. Nevertheless, the flowing-out of funds from agriculture to the other sectors began to be obvious since late 1980s, due to the deepening reforms and accelerating growth of non-agricultural industries. Funds are

[1] Monitoring Survey Bulletin of Farmer Labors 2009, issued by China National Bureau of Statistics in 2010 (http://www.stats.gov.cn/tjfx/fxbg/t20100319_402628281.htm).

mainly channeled in forms of: (1) agricultural and related tax, including agricultural tax[1], animal husbandry tax, farmland tax, special agro-product tax and deed tax, etc. In 2006, the fiscal revenue from agricultural and related taxes was 108.4 billon yuan, accounting for 3.11 percent of the total taxes (CSYB, 2007). It is estimated that including the taxes of township enterprises while deducting public subsidies to agricultural, 2417,07 billion yuan was transferred to non-agricultural sectors (X. Ren, 2010); (2) balance of the deposits and loans of rural financial institutions[2], where a total of 3148.39 billion yuan was transferred to the other sectors from agriculture in 1994-2006 (F. Cai, *et al* 2008); (3) In 2004, the fixed purchase prices were completely abolished and grain prices are began to be fully determined by the market. Before that, the existence of scissors difference between the industrial products and the agricultural products lead to out-flow of funds to non-agricultural sectors as well. According to the estimation of Y. Han (2011), the annual funds transferred out of agriculture in forms of price differences amount to 90.7 billion yuan in average.

The fundamental causes of the continuing funds outflow from agriculture lie in: (1) poor profit margins (Fig.1-1) and high risks of agriculture, while laggard agriculture insurance[3]; (2) small-scaled farming mode requires only inputs of seeds, pesticides, fertilizers, etc, while labor costs is ex-post compensation, requiring no cash payment in advance, thus the funding needs of agricultural production is not very high; (3) low level of social security and narrow investing channels leading to high level of precautionary savings among the farmers; (4) migrant employment raised farmers' expenditure outside of agriculture.

To Channel more funds to agriculture, and transform the lack of fiscal inputs on agricultural, it necessary to ensure funding sources of agriculture, including the government departments and financial institutions. In the first place, continue to increase production subsidies to farmers, and the newly added subsidies should be allocation with priorities to the major grain producing areas, adoption of key varieties, professional and large farms, specialized farmer cooperative organizations. Secondly, further reforms are needed upon the agricultural budgets; the investment on

1 Agricultural tax is imposed on collectives and individuals engaging in profit-making agricultural productions, commonly known as *public grains*. It came into force on June 3, 1958, and abolished from January 1, 2006.

2 Since 1997, the four state-owned commercial banks of ICBC, ABC, CCB and BOC, merged their rural branches under county levels. At present, the rural formal financial institutions mainly include Rural Credit Cooperatives and the China Postal Savings Bank.

3 Until 2010, the annual premium of agricultural insurance was 13.57 billion yuan, providing insurance for 77.33 million hectare of sown crops, accounting for less than half in total.

agricultural infrastructure construction, with priorities on the construction of irrigating and water conservancy facilities; subsidies on the purchase of agricultural machinery and quality seeds. Meanwhile, financial institutions are expected to set up more grassroots agencies, create preferential prerequisites to provide more loans to farmers. In addition, the development of agricultural insurance needs to be accelerated with further diversified services and larger coverage, reducing agricultural production risks (X. Ren, 2010; Y. Yao, 2011).

8.3.5 Increasing the value-added of agricultural products

According to the results of DEA analysis, large increasing margins of net profit and the ratios of net profit within total revenue are detected. Hence, to improve production efficiency, it is necessary to increase the value-added of agricultural products.

Despite of the largest physical outputs of many agro-products, including the cereals, meat, fruits, etc (CSYB, 2010), processing levels of most agro-products are relative low in China, thus with poor value-added and competitiveness in global market. At present, the ratios of processed and deeply processed agro-products are 90 and 80 percent among developed countries, while the two indices in China are 45 and 30 percent, respectively (Y. You, 2010).

In essential, the marketing of agricultural products should be facilitated through construction of infrastructure, easier access and favorite policies to reduce transaction costs. In particular, Green Channels for the transportation of fresh agro-products[1] and direct associations between corn farmers and enterprises should be reinforced, thus shortening the marketing chain and corresponding costs. Moreover, the value of byproducts, e.g., the straw and cob of corn, should be cultivated through the development of relevant industries (Q. Yang, 2008).

Meanwhile, for the enterprises primarily processing agro-products, the values can be added through: (1) adopting the safety insurance system of GAP (Good Agricultural Practice) in farming stages and HACCP (Hazard Analysis and Critical Control Point) in processing stages, in addition to the certification of pollution-free agricultural products, green food and organic food; (2) mining particular characteristics of the products, from the natural environment and cultural background; (3) establishing the brands of local agricultural products, hence creating different imaginations of quality and price in extending specialty market; (4) improving the product packaging and marketing

[1] To promote the circulation of agricultural products and farmers' income, the Green Channel Project was carried out by seven Chinese ministries in January 2005, which provides that reduce or waive the tolls of vehicles legally transporting prescribed fresh agro-products with total freight. Since December 2010, this favorable term extended to vehicles transporting fresh agro-products outside of the prescription no more than 20% of total freight.

services. On the other hand, the enterprises deeply processing agro-products can add the value of their products though technological innovations and adoption of high-tech equipments, in addition to the countermeasures above (Y. You, 2010).

8.3.6 Strengthening social management and education on safe agro-production

Through the field surveys, toxic pesticides are being used widely; farmers are observed with possessing traditional perceptions and behaviors on agricultural production, especially the application of agro-chemicals.

Different from the industrial and urban pollutions, the non-point agricultural pollution is relating to scattering individual farms, which make it is difficult to assess the subsequences and taking unified countermeasures. Simultaneously, due to the limited income of the farmers, it is not suitable to establish punishment-based mechanism, or impose pollution charge to farmers. Therefore, farmers' enthusiasm needs to be simulated through public education and proper compensation institutions (L. Zhu, 2011).

On one hand, through extensive publicity and education, farmers can improve their appropriate perceptions and farming behaviors, especially the application of agro-chemicals, e.g., the balance of necessary ingredients, proper recycles of the used packages, etc. On the other hand, practical technical training and guidance are necessary to improve farmers' capability of adopting knowledge and techniques related to environmental protection and ensuring safety of agricultural products (Z. Jin, 2011). The government should increase the support to rural households and individuals engage in green agricultural production, e.g., the adopting of methane facilities, biological pest-control techniques, etc, through specific subsidies, thus setting up modes for the other farmers (X. Lin, *et al* 2011).

At the same time, to improve regulation on the production, circulation and use of agro-chemicals, severe inspections are necessary firstly, with priorities on toxic chemicals. In addition, endeavors are indispensible to reduce the prices of low-toxicity pesticides, bio-pesticides, and accelerate the development of new product, through financial subsidies, tax-relieves, etc (P. Wang, 2011).

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List of Related Publications

Refereed papers

[1] D. Li, T. Nanseki, K. Hotta, S. Shinkai. Feb., 2011. A factor analysis of Chinese agricultural development using production function: the inputs change and technological progress, 1983-2006. Japanese Journal of Food, Agricultural and Resources Economics, Vol. 61, No. 2: 1-10 (in Japanese, Chapter 2)

[2] D. Li, T. Nanseki, K. Hotta. Sep., 2011. Measurement of wheat production efficiency and the determinants in different counties of Hebei province, China: A model based on two-stage DEA. Japanese Journal of Farm Management, Vol. 49, No. 2: 111-116 (Chapter 3)

Non-refereed papers

[3] D. Li, T. Nanseki, S. Takeuchi. Sep., 2011. Measurement of corn production efficiency in different counties of Hebei Province, China: a model based on DEA. Journal of Faculty of Agriculture, Kyushu University, Vol. 56, No. 2: 409-415 (Chapter 4)

[4] D. Li, T. Nanseki, S. Takeuchi. Feb., 2012. Measurement of agricultural production efficiency and the determinants in China based on a two-stage DEA approach: a case study of 99 farms from Hebei province. Journal of Faculty of Agriculture, Kyushu University, Vol. 57, No. 1: 235-244 (Chapter 5)

[5] D. Li, T. Nanseki, S. Takeuchi. Feb., 2012. Farmers' behaviors, perceptions and determinants of fertilizer application in China: evidence from six eastern provincial-level regions. Journal of Faculty of Agriculture, Kyushu University, Vol. 57, No. 1: 245-254 (Chapter 6)

[6] D. Li, T. Nanseki, S. Takeuchi. Feb., 2012. Farmers' behaviors, perceptions and determinants of pesticides application in China: evidence from six eastern provincial-level regions. Journal of Faculty of Agriculture, Kyushu University, Vol. 57, No. 1: 255-263 (Chapter 7)

List of Related Presentations

[1] D. Li, T. Nanseki, K. Hotta, S. Shinkai. A factor analysis of Chinese agricultural development using production function: the inputs change and technological progress, 1983-2006. The 3rd Symposium of the Food, Agricultural and Resources Economics Society of Japan, Sep. 13, 2009, Takeo City, Saga Prefecture (in Japanese, Chapter 2)

[2] D. Li, T. Nanseki, K. Hotta. Measurement of wheat production efficiency and the determinants in different counties of Hebei province, China: a model based on two-stage DEA. The 80th Symposium of the Farm Management Society of Japan, Sep. 19, 2010, Akita City, Akita Prefecture (Chapter 3)

[3] D. Li, T. Nanseki, S. Takeuchi. Measurement of agricultural production efficiency and the determinants in China based on a two-stage DEA approach: a case study of 99 farms from Hebei province. The 81st Symposium of the Farm Management Society of Japan, Sep. 11, 2011, Tsu City, Mie Prefecture (Chapter 5)

[4] D. Li, T. Nanseki, S. Takeuchi. Study on farmers' application of chemical pesticides and determinants in China: based on a survey to six eastern provincial-level regions. The 5th International Symposium on the East Asian Environmental Problems (EAEP), Nov. 14, 2011, Fukuoka City, Fukuoka Prefecture (Chapter 7)

Acknowledgments

I would like to express my gratitude to my supervisor, Dr. Nanseki Teruaki, whose expertise, understanding and patience, added considerably to my experience being a Doctoral candidate. I appreciate his vast knowledge and expertise in many areas, and his assistance in formulating and reporting the academic ideas (i.e., grant proposals, chances to be member of interesting research projects, artistic techniques in designing the slides and writing the literature). I would like to thank Dr. Takeuchi Shigeyoshi, the Assistant Professor of our laboratory, for his sincere advices and assistance in my study and life. At the same time, I should acknowledge Dr. Hotta Kazuhiko and Dr. Shinkai Shoji, my former Associate Professor and Assistant Professor, for their kind encouragement and constructive comments to my study.

Very special thanks are owing to Dr. Yoshida Taiji and Dr. Fukuda Susumu, for their kindness to join in the dissertation committee of this thesis, and for their enthusiasm to review the whole text and raise instructive comments and suggestions. Without the kind assistance and encouragement from the Professors of this dissertation committee, I will be far from completing this thesis and applying for a Doctor Degree.

I must also acknowledge Ministry of Education, Science, Culture, and Sports of Japan (MEXT) and China Scholarship Council (CSC) and other concerning government agencies, for funding and facilitating my study and living in Japan. Appreciation should also go out to the staff of Kyushu University, for their efficient and warm-hearted assistance throughout my PhD program. Thanks are owing to Ms. Yoshii Aya, secretary of our laboratory, and many other young people who studies in the same laboratory, for their valuable suggestions and assistance to both my study and life. Over the past years, I have shared so many insights and happiness from their wonderful experiences and diversified knowledge, which will be the lifelong spiritual treasure for me in the future.

Meanwhile, I should extend my special appreciation and thanks to Dr. Zhang Yizhen, former Vice President of Hebei Agricultural University, China; Dr. Sun Wensheng, Professor with Hebei Agricultural University, China; Dr. Sun Shifang, former Vice President of Hebei Academy of Social Sciences (HASS), China; Dr. Peng Jianqiang, Director of the Rural Economy Institute, HASS; and my other colleagues with the same academy. Special thanks are owing to Mr. Zhang Qing, Price and Cost Inspection Bureau of Hebei Province, China; Mr. Zhi Lifu, Shijiazhuang Vocational Technology Institute, China; and Ms. Li Xiaojing, Shijiazhuang University of Economics, China. I recognize that this study would not have been possible without their support from applying for the scholarship, coming and studying in Japan, and collecting the necessary data and literature.

The Data of farmers' application of agricultural chemicals is collected thanks to the kind cooperation of Dr. Song Min, Vice-director with Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences; Dr. Chen Tinggui, Associate Professor with College of Economics and Management, Shanghai Ocean University, China; and the other staff with those institutions. Without their efficient and quality assistance in interviewing the farmers, rearranging the data, and the sincere and instructive comments on the symposiums held in Beijing, Shanghai and Fukuoka, I cannot finish this thesis on schedule.

I would also like to thank my family, for the love and support they provided through my life. Although separating by thousands of miles, the encouragements and warmth from them are always the best reasons for me to go on striving for academic excellence. Meanwhile, I must acknowledge my friends in China and Japan, for their sharing of knowledge, skills, and venting of frustration during my PhD program, which helped enrich the experience.

Appendix

I. Questionnaire on the agricultural production efficiency of farms

Objectives: getting complete data about the annual inputs and outputs in crop-farming from the micro-level of separate farms; quantifying the significant social and natural factors that may affect crop production; setting up the database for quantitative analysis of production efficiency and the effects of determinants.

Survey field: farms in Hebei province, China

Date: Aug.-Sep., 2010

Survey methods: interview and correspondence

Location: County Township Village

1. Farm members:

Name	Gender	**Age**	**Schooling years**	**Agricultural labor or not** [a]	Relationship with farm head
					Farm head

[a] Agricultural labor includes male aged in16-65 years and female aged in 16-60 years, who are healthy enough to engage in common agricultural work and stay at home more than 6 months in a year.

Objectives: 1) overview of the composition of each farm; 2) age of farm leader (d_7), number of agro-labors (d_1), average schooling years of the labors (d_8), will be important determinants that affecting agricultural production.

2. Agricultural production conditions:

(1) Arable land and irrigable conditions in 2009 (*mu*):

Total	Contracted land [a]			Borrowed land [b]		
		Irrigable	Non-irrigable		**Irrigable**	Non-irrigable

[a] Arable land owned through *household contract responsibility system*; [b] Arable land borrowed from the collectives and other farms.

(2) Agricultural Machines [a] owned by the farm:

Machine	Combine	Tractor	Tiller	Seeder	Thresher		
Date of bought							
Value (yuan)							
Power (kw)							

[a] Including machinery used in agricultural planting, breeding, processing, transportation and farmland fundamental construction, being powered by diesel, gasoline, electricity and other energies, such as hydro, wind, coal, solar, etc.

Objectives: 1) overview of the basic agricultural conditions, including the *circulation of farmland* can be referred as a determinant (d_9); 2) formulating *farm size* (d_2) by the total area of land, *irrigation level* (d_3) by percentage of irrigable land, and *mechanization level* (d_5) by power of agricultural machines, to form other important determinants that affecting agricultural production.

3. Crops and inputs per *mu* in 2009:

(1) Fertilizer and pesticide used per *mu*:

	Fertilizer										Pesticide					
	kg	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*
Wheat																
Corn																
Rice																
Cotton																
Vegetable																

(2) Calculation of total inputs per *mu*:

Crop	**Land rent**	**Seeds**			**(Fertilizer)** [a]		**(Pesticide)**		**Machinery**			**Irrigation**		**Labor**		
		Self	Bought						Self	Hired				Self	Hired	
	yuan	*kg*	*kg*	*yuan*	*kg*	*yuan*	*kg*	*yuan*	*mu*	*mu*	*yuan*	*mu*	*yuan*	*day*	*day*	*yuan*
Wheat																
Corn																
Rice																
Cotton																
Vegetable																

[a] Columns titled in ( ) can be calculated by the surveyors later without asking the farmers.

Objectives: 1) general idea about the crops and the corresponding inputs in each farm; 2) *labor inputted* (x_1), *land rent inputted* (x_2), *seeds inputted* (x_3), *fertilizer inputted* (x_4), *pesticide inputted* (x_5), *machinery service rent* (x_6) and *water inputted* (x_7) can be supported with specific data, including the conversion of self-owned inputs; 3) other information including ratio of hired labor, etc., can be derived as well.

4. Crops and outputs:

(1) Please write down the money you got through selling the main products in 2009.

	Market value				Market value				Market value			
	date	*kg*	*yuan/kg*	*yuan*	*date*	*kg*	*yuan/kg*	*yuan*	*date*	*kg*	*yuan/kg*	*yuan*
Wheat												
Corn												
Rice												
Cotton												
Vegetable												

(2) Calculation of net profit

	(Sales volume)[a]		(Average price)	**Yield**	(Value)	Sown area	Value of by-products*		(Total value)	(Total input)	**(Net profit)**
	kg	*yuan*	*yuan/kg*	*kg/mu*	*yuan/mu*	*mu*	*yuan*	*yuan/mu*	*yuan/mu*	*yuan/mu*	*yuan/mu*
Wheat											
Corn											
Rice											
Cotton											
Vegetable											

[a] by-products include the straws, corncob, etc.

Objectives: 1) general ideas about the outputs and price of different crops; 2) *yield of main product* (y_1) and net profit (y_2) of each crop are basic outputting variables in the measurement of agricultural production efficiency.

5. Fiscal subsidies:

Please write down the agricultural subsidies you got from the government in 2009.

	Total	Category						
mu								
yuan								
yuan*/*mu								

Objectives: 1) general ideas about the subsidies in the sampled regions; 2) the data of *agricultural safeguard level* (d_6) by the total subsidies per *mu*, can be adopted in models appraising the determinants.

6. Access to credit:

(1) **Times** of borrowing money from commercial banks or credit cooperatives for *farming* in 2007-2009 (   ):

(2) **Times** of borrowing money from commercial banks or credit cooperatives for *any purpose* in 2007-2009 (   ):

①None ②1-3times ③4-5times ④more than 5 times

Objectives: 1) viewing the popularization of agricultural sciences and technologies in the sampled regions; 2) being a major way to support the agriculture, the access to sci-tech services is affecting agriculture, thus the data of *access to credit* (d_{10}) can be adopted in models appraising the determinants as dummy variables.

7. Extension of agricultural technologies:

(1) **Times** of agricultural sci-tech services you have got from the government in 2007-2009 (   ):

(2) **Times** of agricultural sci-tech services you have got from the society in 2007-2009 (   ):

①None ②1-3times ③4-5times ④more than 5 times

Objectives: 1) viewing the popularization of agricultural sciences and technologies in the sampled regions; 2) being a major way to support the agriculture, the access to sci-tech services is affecting agriculture, thus the data of *Extension level* (d_5) can be adopted in models appraising the determinants as dummy variables.

II. Questionnaire on farmers' behaviors and perceptions on agricultural pollution

调查员编号：

农 业 污 染 现 状 与 公 众 认 知 情 况 调 查 问 卷

为准确了解农业污染对您生产生活的影响，支持相关课题研究和政府决策，我们组织了这次问卷调查。通过问卷所获取的数据资料将全部用于相关研究，而不直接对外公布。因此，希望您能够如实反映所了解的情况。

衷心感谢您的配合与支持！

〇〇〇〇研究所

年　　月

家庭住址：　　省（区、市）　　县 （市、区）　　乡（镇）　　村　　受访者：　　调查日期：

一、农户基本情况

1. 家庭成员状况：

与户主关系	是否受访者[a]	性别	年龄	文化程度[b]	2010 年外出打工天数[c]	2010 年外出打工收入（元）
户主				①　②　③　④　⑤		
				①　②　③　④　⑤		
				①　②　③　④　⑤		
				①　②　③　④　⑤		

注：[a]请在对应受访者信息的栏内划“√”或“〇”；[b]“文化程度”分为①文盲、②小学、③中学、④高中、⑤高中以上，划“√”或“〇”选择相应类别的编码即可；
[c]外出打工是指从事县域以外的工作，且一般不每天回家居住。

2. 您家 2010 年全年的现金收入是（　　）：① 1 万元以下　　② 1 万－3 万元以下　　③ 3 万－5 万元以下　　④ 5 万元及以上

3. 2010 年您家农作物产销情况：

农作物[a]	播种面积（亩）[b]	总产量（公斤）	其中：出售数量（公斤）	销售总收入（元）

[a]农作物主要包括粮食、棉花、油料、糖料、麻类、烟叶、蔬菜和瓜类、药材和其他农作物九大类；[b]指实际播种或移植有农作物的面积。凡是实际种植有农作物的面积，不论种植在耕地上还是种植在非耕地上，均包括在农作物播种面积中。在播种季节基本结束后，因遭灾而重新改种和补种的农作物面积也包括在内。

4. 2010 年您家畜禽产品产销情况：

畜禽种类	养殖数量（头、只）[a]	出栏数量（头、只、公斤）[b]	出售畜禽产品数量（头、只、公斤）[b]	销售总收入（元）

[a]指 2010 年 12 月 31 日当时饲养的大牲畜、猪、羊、家禽等畜禽的存栏数；[b]指 2010 年出栏销售的畜禽数量，包括蛋、皮、毛和屠宰后的肉等。

二. 农村生活方式

1. 您家主要怎样处理废旧玻璃制品、旧书报、废旧布料等可回收的生活垃圾？（ ）（单选）

①出售 ②烧掉 ③随意扔掉 ④交由统一处理 ⑤填埋 ⑥

2. 您家一般怎样处理厨房垃圾？（ ）（单选）

①饲喂牲畜 ②随意倒掉 ③堆肥 ④交由统一处理 ⑤

3. 您家一般怎样处理人畜粪便？（ ）（单选）

①直接还田 ②用作堆肥 ③随意扔掉 ④交由统一处理 ⑤沼气发酵 ⑥销售 ⑦

4. 您家一般怎样处理不可销售的塑料垃圾？（ ）（单选）

①填埋 ②烧掉 ③随意扔掉 ④交由统一处理 ⑤

三、农业生产方式

1. 您家选择购买化肥、农药时，最优先考虑的因素是？（ ）（单选）

①价格 ②增产效果 ③销售者 ④他人是否使用 ⑤售后服务 ⑥对环境的影响 ⑦

2. 您家使用化肥、农药时，最优先考虑的因素是？（ ）（单选）

①成本 ②增产效果 ③对环境的影响 ④对施肥者的影响 ⑤对农产品质量的影响 ⑥

3. 您家确定化肥、农药使用量的最主要依据是？（ ）（单选）

①使用说明 ②个人经验 ③技术指导 ④他人的使用量 ⑤

4. 您家购买动物饲料和兽药时，最优先考虑的因素是？（ ）（单选）

①价格 ②使用效果 ③销售者 ④他人是否使用 ⑤售后服务 ⑥

5. 您家使用动物饲料和兽药时，最优先考虑的因素是？（　　）（单选）

①成本　②使用效果　③对环境的影响　④对施肥者的影响　⑤对畜产品质量的影响　⑥

6. 2010 年您家的肥料使用情况：

农作物	化学肥料												是否辅施农家肥	
	尿素													
	公斤	次数	施用方法	公斤	次数	施用方法	公斤	次数	施用方法	公斤	次数	施用方法	是	否
小麦														

7. 2010 年您家的农药使用情况：

农作物	化学农药												是否利用生物防除措施[a]	
	公斤	次数/季	施用方法	公斤	次数/季	施用方法	公斤	次数/季	施用方法	公斤	次数/季	施用方法	是	否
小麦														

[a] 生物防除措施指为减少化学农药的使用量，利用某些生物分泌的气味和食物特性等，对其他某些生物生长进行抑制的技术措施。例如，利用洋葱的气味杀死导致小麦黑穗的病菌，在玉米田中间作豆角以吸引一些益虫来捕食害虫，在稻田中养鱼、鸭防除杂草，等。

8. 2010 年您家动物饲料的使用情况：

畜禽种类	购入混合饲料									自家制青贮饲料使用情况		是否使用添加剂	
	公斤	喂饲次数/天	喂饲天数	公斤	喂饲次数/天	喂饲天数	公斤	喂饲次数/天	喂饲天数	公斤	喂饲次数/天	是	否

9. 您知道农药的停药期吗？（　　）（单选）

①非常了解　②比较了解　③听说过　④不了解

10. 您觉得过多施用化肥会产生哪些结果？（　　　　　）（多选）

①作物倒伏　②土壤板结　③水质污染　④作物增产　⑤不了解　⑥

11. 您觉得过多施用农药会产生哪些结果？（　　　　　）（多选）

①危害喷施者健康　②危害食品安全　③污染环境　④提高杂草和病虫害控制效果　⑤不了解　⑥

12. 您家使用塑料农膜的情况怎样？（　　）（单选）

①经常使用　②有时使用　③很少使用　④几乎不使用　⑤从来不使用

13. 您在施肥后一般怎样处理化肥包装袋？（　　）（单选）

①洗净留作他用　②烧掉　③随意扔掉　④交由统一回收　⑤

14. 您在喷施农药后，一般怎样处理农药包装？（　　）（单选）

①洗净留作他用　②烧掉　③随意扔掉　④交由统一回收　⑤

15. 您一般怎样处理废旧农膜？（　　）（单选）

①填埋　②烧掉　③随意扔掉　④交由统一回收　⑤没有用过　⑥

16. 您一般怎样处理病死畜禽的尸体？（　　　　）（多选）

①掩埋　②烧掉　③随意扔掉　④自家食用　⑤交由统一处理　⑥出售　⑦

四、对农业污染的认知

1. 在您看来，当前您周边最主要的农业污染源是？（　　）（单选）

①工业废弃物　②城镇生活垃圾　③农村生活垃圾　④化肥和农药等农业生产物资　⑤　⑥不知道

2. 在您看来，当前您周边最具污染性的农业生产物资是？（　　）（单选）

①化肥　②农药　③农家肥　④塑料农膜　⑤　⑥不知道

3. 您认为产生农产品受污染的最主要环节是？（　　）（单选）

①农业生产　②收获　③加工　④运输　⑤销售　⑥消费　⑦　⑧不知道

4. 您如何看待自己生产并用于销售的农产品的安全性？（　　）（单选）

①非常安全　②比较安全　③有些不安全　④非常不安全　⑤不清楚

5．当前，依据农产品质量特点和对生产过程控制要求的不同，我国将农产品分为一般农产品、认证农产品和标识管理农产品。其中，认证农产品又分为无公害农产品、绿色农产品和有机农产品。您认为这三类认证农产品的质量安全等级排序是？（　　）（单选）

①绿色＞有机＞无公害　②有机＞绿色＞无公害　③无公害＞有机＞绿色　④无公害＞绿色＞有机　⑤三者相同　⑥不知道

6．有机农产品在生产加工过程中禁止使用农药、化肥、激素等人工合成物质和基因工程技术，并对地块和产量有明确要求。对于此类安全优质农产品，您能够接收其高于一般农产品的价格幅度是？（　　）（单选）

①10%以内　②10%-20%　③20%-50%　④50%-100%　⑤100%-300%　⑥300%以上　⑦不知道

7．关于农产品质量安全情况，您最主要的信息获取渠道是？（　　）（单选）

①政府的通知通告　②报刊杂志的报道　③广播电视的报道　④亲朋好友　⑤科研报告　⑥商品包装　⑦

8．关于农产品质量安全情况，您最相信谁发布的信息？（　　）（单选）

①政府的通知通告　②报刊杂志的报道　③广播电视的报道　④亲朋好友　⑤科研报告　⑥商品包装　⑦

9. 在您看来，谁应当为农业污染承担首要责任？（　　）（单选）

①政府　②农民　③化肥和农药等农用物资的生产者　④消费者　⑤　⑥不知道

10. 在您看来，遏制农业污染最有效的途径是？（　　）（单选）

①完善农业环保立法　②推广环保型农业技术　③补贴农业环保行为　④加大农业污染处罚力度　⑤扩大农业经营规模　⑥

调查问卷到此结束，非常感谢您在百忙之中接受我们的访问！对于本次调查的内容和方式，以及如何更好防控农业污染，欢迎您提出宝贵意见。