An analysis of the impact of land fragmentation on agricultural production cost. Evidence from farmers in Gansu province, P.R. China.

Mengxuan He
Registration number: 911003314130
Supervisor: Dr. NBM (Nico) Heerink
Dr. J (Janneke) Pieters

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Summary

China has enormous population and very limited arable land resource. Land fragmentation is generally taken as an obstacle to the optimization of land use efficiency. In spite of the disadvantages, land fragmentation can have some positive influence on the agricultural production since it can smooth the production risk.

Some researchers did the research on the effect of land fragmentation on the rice production cost based on the data on South China. This thesis focuses on the effects of land fragmentation on the wheat production cost in Northwest China. A model based quantitative assessment is presented in this thesis. The following six questions are answered: (1) What are the trends in land fragmentation in China and its main regions since the beginning of the 1980s? (2) How does land fragmentation influence the agriculture production? (3) How can land fragmentation be measured? (4) What does the agricultural production cost of the surveyed households in northwest China consist of? (5) What is the impact of land fragmentation and other factors in agricultural production costs in northwest China? (6) To what extent do land fragmentation and its impact on production costs differ between South and Northwest China? We find that since the mid 1980's, the degree of land fragmentation is decreasing and dropped rapidly since the Sloping Land Conversion Program was initiated in 1999. Besides, we find that land fragmentation, which is measured by the Simmons Index, affects total production cost per unit of output negatively in two of the five irrigation districts in the research area in Northwest China and does not have a significant impact in the other three irrigation districts. For the production cost categories, the influences of the Simmons Index and farm size are found to be similar. In South China, farms tend to substitute labor for other inputs when facing greater land fragmentation while total production costs are not affected . However, farmers in two of the five irrigation districts in the research area in Northwest China have lower total production costs per unit output when land fragmentation is larger.

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1. Introduction

As a developing country, China has registered a remarkable economic progress. The improved living standard incurs concomitant problem of the tremendous resource consumption, attracting many researchers' concerns. China is known for its largest population of more than 1.3 billion (2013) in the world with which China's increasing demand for resource and food products leads to an international debate on Who Will Feed China (Jiang, 2011). To ensure the food supply, the government set a goal of at least 95% grain self-sufficiency, for which a red line of available cultivated land is formulated (120 million hectares). Given the enormous population, China has a very limited arable land resource. Furthermore, the total cultivated area of China keeps decreasing, and it has dropped from 129.205 million hectares to 121.735 million hectares since 1999 until 2007 (Li, 2011). In 2008, In detail, only 13.5% of the total land resource can serve for agriculture production, equaling less than 0.10 ha per capita (Tan et al., 2008).

In the context of arable land being declining, a higher land productive efficiency is called for to improve the food production volume. In China, land fragmentation is an obstacle to the optimization of land use efficiency, generating widespread concerns from the Chinese government and researchers. Land fragmentation is defined as the situation in which the farmland consists of spatially separate parcels (McPherson, 1982). China is one of the countries facing the most severe land fragmentation since the reform of the household responsibility system (HRS) in 1981. Under this system, the households are responsible for their own profits and losses. The reform eliminated the traditional Maoist organization of the rural economy, which advocated the collective ownership and management on the farmland. Under the HRS, land was distributed based on family size, number of laborers or a combination of both. The homogenous plots are classified into the different group, according to the soil type, land use type, irrigation condition and drainage condition (Kung, 2000). In spite of the remarkable success, this system exposes several inherent weaknesses in the practice. This thesis only introduces its limitations from the land fragmentation perspective.

Generally speaking, the limited cultivated land is distributed among the villages under the egalitarianism principle, exacerbating the land fragmentation. In detail, the HRS results in a greater land fragmentation from two aspects: Firstly, the total arable land consists of many fragmented farming units and it is owned by all the villagers collectively and the farming units are distributed to all the households in the village. Provided the abundant population and limited farming land size, the villagers who have the similar land property rights only have pieces of small lands. Besides, the boundaries and paths separate the land areas between the different holdings, decreasing the farmland further. Furthermore, the parcels of farmland are different by their characteristics, e.g., soil type, irrigation condition, etc. Within a hamlet, the plots which are homogeneous in major characteristics (quality, irrigation conditions, etc.) are classified as one category. Households obtained use rights of at least one plot of each category, based on the size of their family and labor force members. Secondly, to maintain the egalitarianism principle, the distribution has to be frequently readjusted to take into account the demographic changes that occurred among households within the village. Under HRS, egalitarianism is the key principle in the land distribution. In the village, every person is supposed to have the same share of land from each land class. To maintain an equal land distribution based on household / labor force size, the land distribution needs to be adjusted to correct for demographic changes. Such land readjustments may also contribute to more severe land fragmentation.

Various literatures (Tan et al. , 2008; Demetriou et al., 2013) have noted that the land fragmentation is expected to impose negative effects on agriculture. Generally speaking, these effects arise for the following reasons: (1) the far apart parcel generates a longer distance between the fields causing an increase in transportation cost and working time; (2) spatially separated farmland may hinder agricultural mechanization, resulting in lower production efficiency.

In spite of the negative impacts of the land fragmentation, potential positive effects are also noted in many studies. Firstly, the land fragmentation smooths the production risk by increasing the product diversity (Fenoaltea, 1976; Heston & Kumar, 1983). In the fragmentation situation, the agriculture product diversity may be increased. Because when the household have several plots which differ in micro-climatic and environmental conditions (fertility, slope, irrigation condition, etc.), they are possible to grow more type of crops or plant a certain type of crop in different plots with various conditions. In this case, the risk of market shock of a certain type of product could be dissolved. Secondly, the spatially separated farmland lowers the risk that the entire crop is affected by the disaster and disease in the same growing season (Li, 2010). Thirdly, in the case of fragmented land, the households are able to seasonally adjust the allocation of the labor, boosting the working efficiency of labor force (Bentley, 1987).

Although many researchers have theoretically argued the twin impacts of land fragmentation on agriculture production cost, the empirical effect is region-dependent since the various production conditions. Provided the complex situation of the land fragmentation, a quantitative analysis of the impact of land fragmentation on agricultural production may provide more insight into the net impact of land fragmentation on productivity. The objective of this study is to provide a model based assessment of the effect of land fragmentation on the wheat production cost in Northwest China. Tan et al. (2008) examined how land fragmentation influences the cost of rice production using data from a survey held in Jiangxi province which is located in the South of China. Considering China has a vast territory, the natural environment, economic development level and geographic conditions are diversified for different regions of China. To get a fuller picture of land fragmentation's impact on production cost, this thesis focuses on the Northwest China. Because in North China, wheat is the main crop instead of rice in South China, we will provide a quantitative analysis on wheat production cost using household survey data from Gansu province in northwest China

The thesis is structured in 6 chapters. After the introduction, Chapter 2 will present the trend of land fragmentation in China since 1980's. In Chapter 3, the data and research area are introduced. Then, an econometric model is developed in Chapter 4. Next, Chapter 5 focuses on the results of the regression analysis. Finally, Chapter 6 concludes and provides a general discussion.

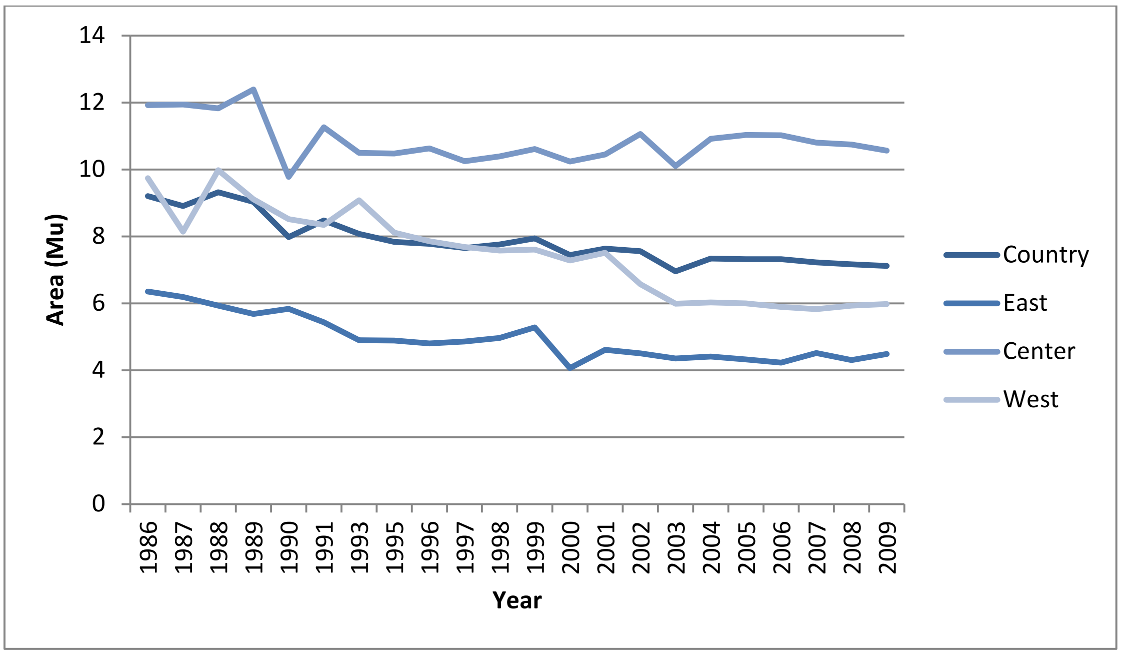
2. Trend of land fragmentation in China since 1980's

This chapter focuses on the trend of land fragmentation in China since 1980's. Section 2.1 presents three figures (Figure 2.1-2.3), indicating the degree of land fragmentation in three regions of China from three perspectives of average area per household, average plot number per household and average area per plot[1]. Section 2.2 provides more details of trend of land fragmentation since the 1980's (Figure 2.4-2.7). The plots are classified into three groups, and the distribution of each group in the three regions is analyzed. The data for the figures are also used by Tan et.al (2006) and only the data before 1999 has been incorporated. This thesis analyzes these trends based on the updated data (1986-2009).

2.1 Land fragmentation in three regions of China

Figure 2.1-2.3[2] presents the degree of land fragmentation in three regions of China from 1986 to 2009.

Figure 2.1 Average area (Mu) per household, 1986-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

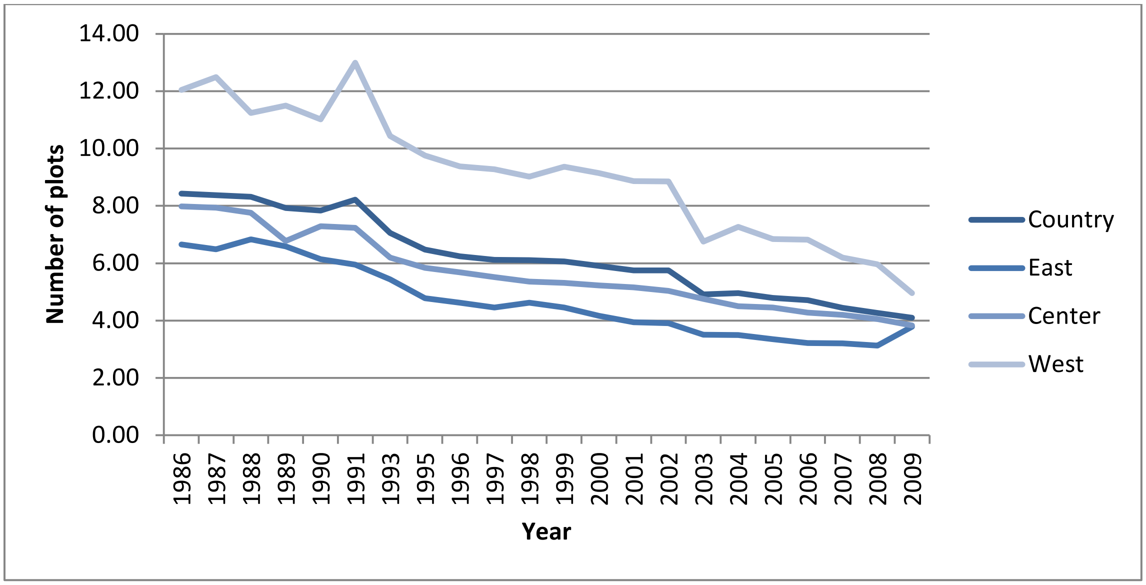
The figure 2.1 shows the trend of average area per household within 23 years since 1986. The figure indicates that over the 23 years, the average area are per household in China showed a downward tendency. From 1986 to 1991, the average area fluctuated and declined from 9.2mu/household to 8.47mu within the 5 years. Since then, it kept decreasing and there was a slight increase in 1999. At 2003, the average area per household reached to the lowest point with 6.95mu per household. By 2009, it decreased to 7.12mu/household. The figure 1 also presents the average area in three economic regions in China (see details in appendix A.1), and it is clear that the central region of China has the largest land area per household, while the Eastern part of china occupied smallest farmland. Among the three regions, the largest decrease in average farmland showed in Western China from 2001 to 2003 caused by Sloping Land

[1] Data for Figs. 2.1–2.7 are from Rural Fixed Observation Office,Central Policy Research Division And agricultural Ministry, P.R. China (1986-1999, 2000-2009). See detail in Table A.2-A.5.

[2] The data of 1992 and 1994 are not available.

Conversion Program (SLCP, also called the 'Grain for Green Program). As the the largest land retirement/reforestation program in China, SLCP was initialed in 1999 and implemented at a large scale since 2002. The aim of SLCP is to convert 14.67 million hectares of sloping cropland to forests by 2010 with particular emphasis on the Western China(Bennett, 2008).

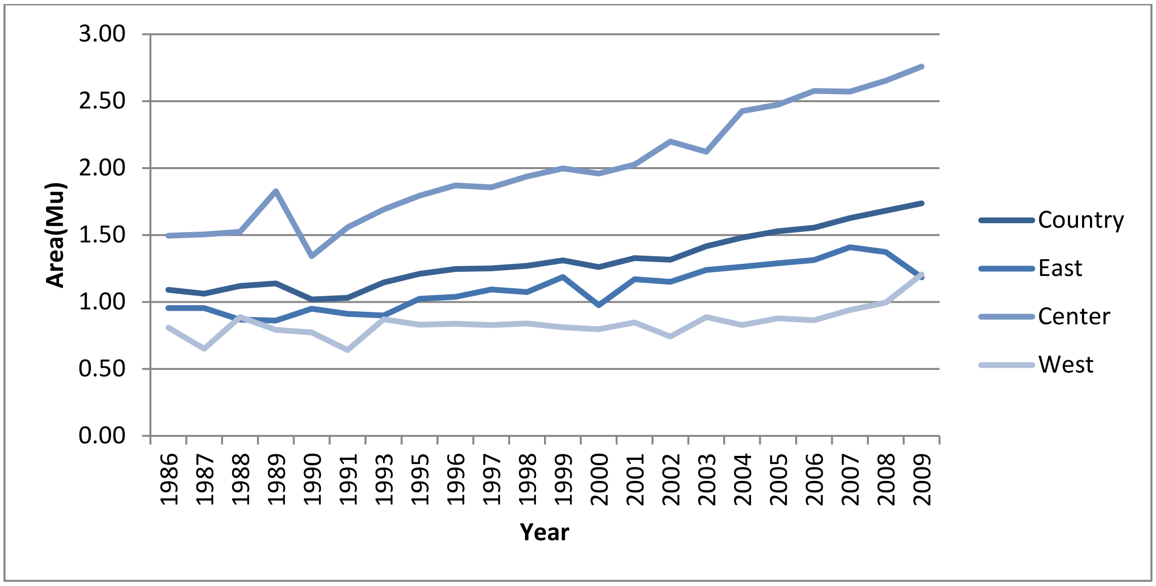
Figure 2.2 Average number of plots per household, 1986-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Figure 2.2 presents the change of average number of plots per household from 1986 to 2009. The slight fluctuation of the average plots number/household can be observed before 1991, after when it kept a downward tendency reached at 4.1 plots/household in 2009, decreasing by 4.33 plots/household during the 23 years. Moreover, we can find that the household in West and East part of China had highest and lowest number of plots, respectively. It is important to note that a tremendous drop of plots number can be observed between 2001 and 2003 resulted from the SLCP, under which the entire plots was taken out of cultivation area.

Figure 2.3 Average area (mu) per plot, 1986-2009[3]



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Based on the data of pervious figures, the average area/plots is derived, presented in the figure 2.3. It is clear that in spite of the small decline in 1990, the average area per plots kept increasing throughout the whole period, getting to 1.74 mu/plots in 2009. Over the 23 years, the average area per plots was highest in the central region of China. Since 1993, the average area per plots stayed the same until 2000, and increased afterwards.

Based on the above analysis, we know that during the past 23 years, both the size of farmland and the number of plots per household decreased, and the latter showed a larger decline. The possible reason for the decreasing plot number are land consolidation, land rental market development and land reallocations (Tan et al., 2006).Besides, we can see that the plot size per household increased, indicating the degree of land fragmentation decline moderatly since 1986. However, the current degree of land fragmentation of China (average land holding size of around 7.12 mu, and 4.1 plots on average in 2009) is higher than the countries who also confronts severe land fragmentation. For example, in Albania the owned land per household is 0.85 hecatare, which equals 12.75 mu[4], and the number of plots is three in 2005 (Deininger et al., 2012).

So it is concluded that that although China faces severe land fragmentation, the degree of it is declining. Besides, we can also conclude that there was a greater degree of land fragmentation in West of China, where the number of plots is higher than other regions and the area of the plot is lower, but the SLCP has been a major factor in reducing land fragmentation in that region.

2.2 Plot size distribution in three regions of China

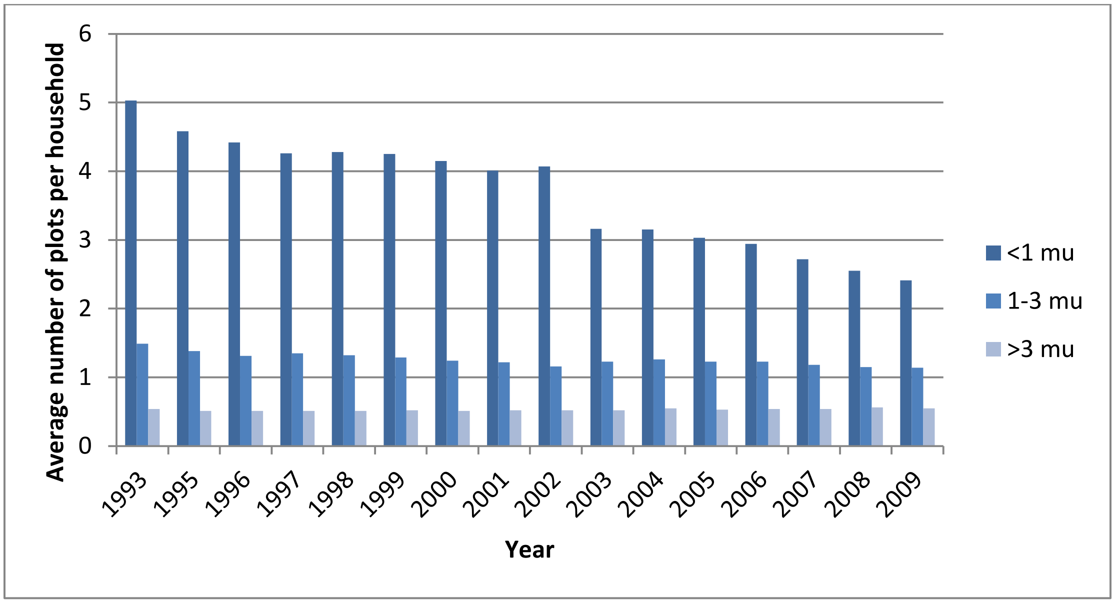
To get an insight of the trend of land fragmentation in China since 1980's, the three regions will be analyzed separately. Figure 2.4-2.7 provide details of plot size distribution in the whole country and each region (see detail in Table A.5). The plots are classified into three groups

[3] The data are calculated based on the data of average area (Mu) per household and average number of plots per household from National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

[4] 1 ha= 15 mu.

based on the size: the first group of plots is smaller than 1 mu and the plots which are between 1 and 3 mu are categorized into the second group. The third group includes the rest of the plot (larger than 3 mu). Figure 4 summarizes the plot size distribution at the national level.

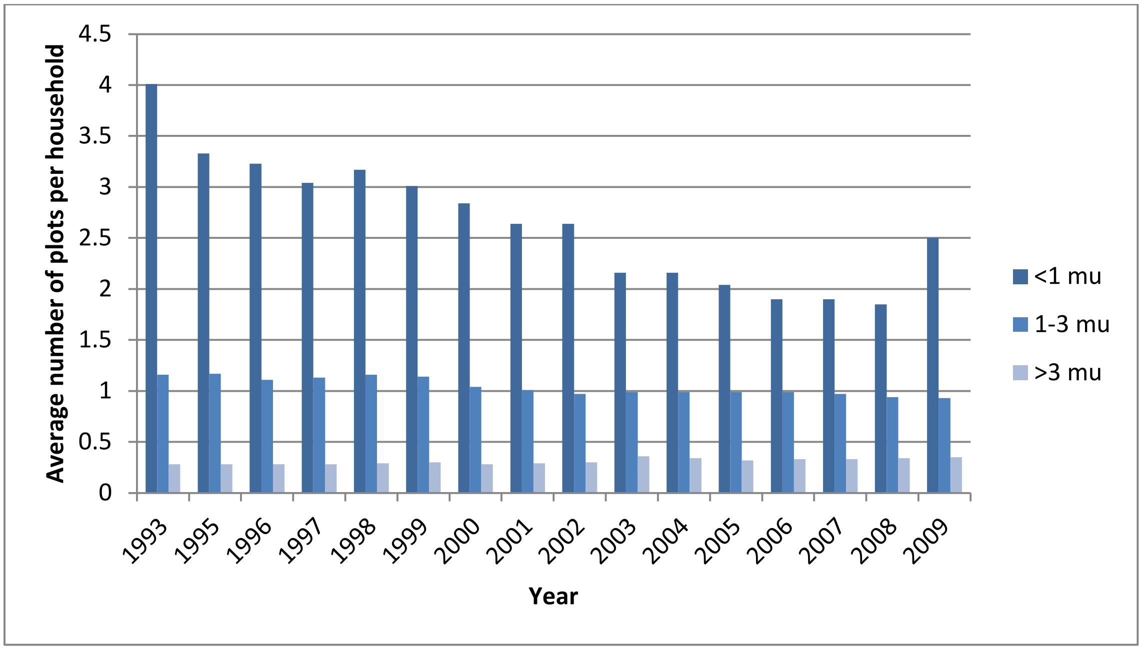
Figure 2.4 Plot size distribution in China, 1993-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

From the figure 2.4, we know that throughout the 1993 to 2009 period, the average number of small plots is much larger than that of medium and large plot. Among the three groups of land, the amount of large and medium plot roughly kept stable, although small fluctuations can be observed in the case of medium plot. The small size of farmland experienced a big decline over the 16 years, from 5.03 mu in 1993 to 2.41mu in 2009. Because of the SLCP, the biggest drop occurred in 2003 where the size of the small plot decrease by 22.36 % (0.91 mu). Next, we will take a look at plot size distribution in East, Center and West of China.

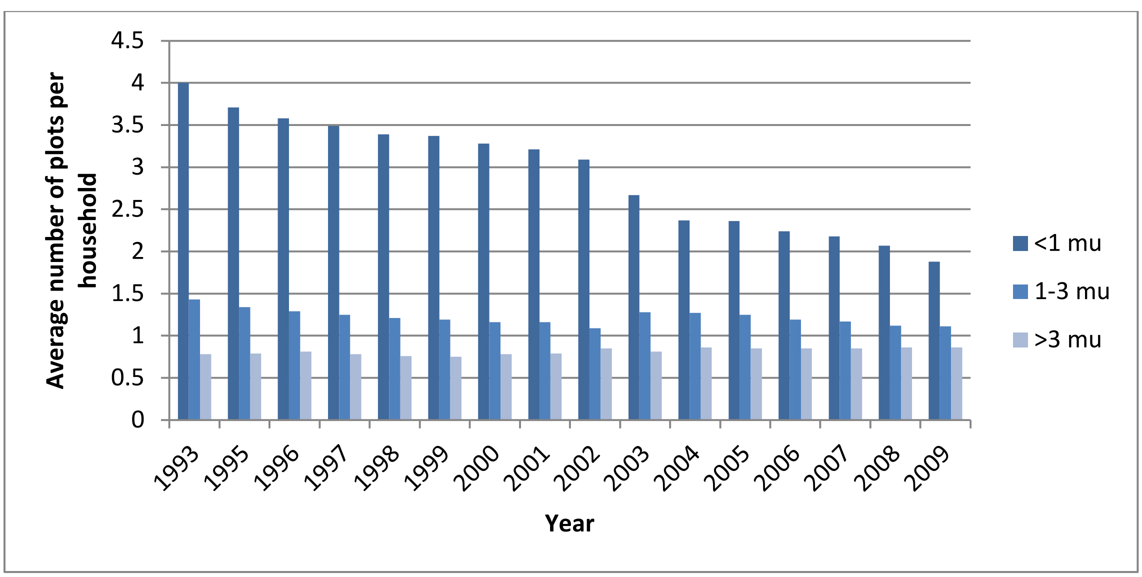
Figure 2.5 Plot size distribution in Eastern China, 1993-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Figure 2.5 indicates that the plot distribution in Eastern region showed the same trend as the national level. Compared to the figure 4, we see the sizes of all the groups of plots in East of China are lower than those of the whole country. In Eastern China, most of the farmlands are the small plots and the large plot has the smallest amount. The average numbers of the large and medium plot are constant, at level of 0.28-0.35 and 0.93-1.16 plots, respectively. The average number of small plots decreased from 4.01 to 2.5 plots from 1993 to 2008; however, a surprising rise is noted in 2009, with an increase of 35.14%. The cause of this sudden increase is unclear.

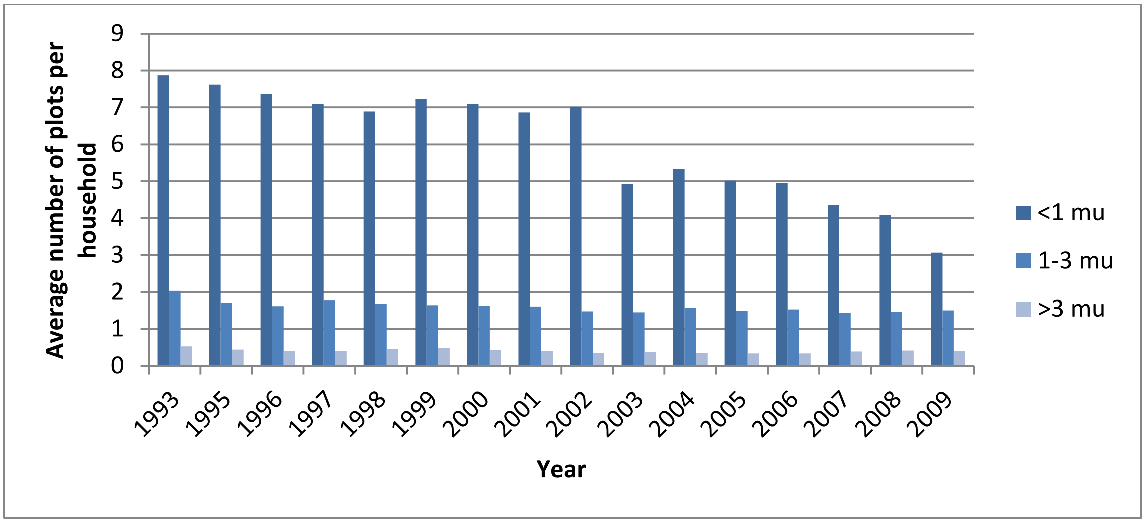
Figure 2.6 Plot size distribution in Central China, 1993-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Figure 2.6 summarizes the plot size distribution in Central China from 1993 to 2009. According to the figure, the average sizes of medium and large plot in Central China are larger than the national level. However, the small plot which has the largest average number among three groups is smaller than the national level. Similar as the East China, the large and medium plot fluctuated within a small range, and it is noted that the number of large plot is about three times more than in the East. Besides, it is clear that the small plot also kept decreasing during the 16 years, declining from 4 to 1.88 mu.

Figure 2.7 Plot size distribution in Western China, 1993-2009



Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Figure 2.7 shows the plots distribution in the Western region. Compared to the national level and another two regions, the average numbers of small and medium plots are higher and a number of large land is smaller in West of China. Likewise, the number of small land experienced the biggest decline, and in 2003 there was also a remarkable drop, which probably casused by the large-scale implementation of the SLCP.

Based on the figure 2.4-2.7, we can conclude that in each region of China, the households were mainly working on the small plots. The figures also confirm the more severe land fragmentation in West of China, where the largest number of small plots and smaller number of large land are observed, and the important role of the SLCP in reducing land fargmentation especially in western China.

3. Data and research area

This chapter introduces the data used for answering research questions 4 – 6 and a brief description of the research area for which these data were collected.

The micro-level variables on production costs, land fragmentation and inputs used are same as Castro et al., (2010), Ma et al. (2009), Zhang et al. (2014), Zhang et al. (2013) and Ma et al. (2013). All the original data were collected through the household survey in Minle county in 2008 as a part of a larger project on economic policy reforms, agricultural conducted by the staffs from Gansu Academy of Social Sciences in Lanzhou, Gansu Agricultural University in Lanzhou and Nanjing Agricultural University in Nanjing. As one of the six counties of the Zhangye city in Gansu Province, Minle is a major agriculture production base in Gansu province.

The total farmland area of Minle is 860,000 mu where wheat, barley and potato are the main crops. The arable land consists of major three agro-ecological zones which reflect differences in planting conditions, shown in the following table:

Table 3.1 Agro-ecological zones in Minle

Agro-ecological zone	Elevation range (m)	Farmland area (mu)	Rainfall level
1	1600-2000	190000	Low
2	2000-2200	500000	Middle
3	2200-2600	170000	High

The survey was conducted in 21 villages from 10 towns in which 317 observations. In each village, 15-16 observations are selected. Table 3.2 presents the major characteristics of the surveyed villages and towns.

Table 3.2 Major characteristics of the surveyed towns

	Minglian	Liuba	Hongshui	Xintian	Sanpu	Yonggu	Nangu	Nanfeng	Fengle	Shunhua
Location										
Number of hamlets	4	3	5	5	3	3	7	3	1	1
Surveyed villages	Wanglang Zhong, Zhujia Zhuang and Xizai Zi	Wuba and Wangguan	Chengguan, Majia zhuang and Xiacai	Erzai,Dawang Zhuang and Yushu Miao	Wujia Zhuang and Sanpu	Tengjia Zhuang	Kezai Zi, Yancheng and Zhouzhuang	Mayintun and Yangjia Yuan	Zhangjiazai	Tujiacheng
Number of observations	45	30	45	45	30	15	45	32	15	15
Agro-ecological zone	1	1	2	1	1	2	1	3	2	2
Population										
Persons	1508	5253	5500	5243	2642	6893	8918	3300	2510	926
Land (Mu)										
Irrigated area	11300	19669	10886	24348	10310	23002	19190	9900	5330	1350
Dry land crop area	500	5600	0	1200	0	600	5076	6610	0	220
Fruit trees area	0	30	0	0	30	0	210	0	0	0
Forest area[5]	569	15	2900	3600	0	3	1800	0	7840	2200
Grassland area	0	0	0	0	0	0	60	50	200	0

[5] Forest area includes firewood forest, economic forest and ecological forest.

Total Area[6]	12369	25314	13786	29142	10340	15065	26336	16560	14170	3770
Water use										
Irrigation district	Tongziba	Hongshuihe	Hongshuihe	Daduma	Hongshuihe	Tongziba	Daduma	Tongziba	Haichaoba	Haichaoba
Village										
Main crops[7]	1,2,3	1,2,3,4	1,2,3,4	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4,5

Source: Based on the field survey.

[6] Sum of area listed and irrigated, dry land, fruit trees, forest and grassland area

[7] 1=Barley，2=Wheat，3= Potatoes，4=Rapeseed, 5=Garlic and 6=Herbs.

It is important to note that in Hongshuihe irrigation area, the water management is computerized, with computer-controlled sluices (from 1st level to 2nd level canals only). Therefore, relatively more high-tech agricultural technologies are applied in this area.

In this thesis, the agricultural production costs cover the cost of labor, irrigation water, seed, chemical fertilizer, pesticides, and machine use. The Labor cost consists of two parts: hired labor and family labor cost which is derived based on the shadow wage rate of family labor, which is assumed to be equal to the average market price (41.27 yuan/day) in agricultal production. In the Chapter 5, the sensitivity of of the total cost with respect to the choice of shadow wage rate is examined. Seed cost is the sum of purchased seed cost and the retained seed cost which is the multiplication of average seed price and quantity. Machine cost is derived based on the oil fee of own machine and the value of hired machine. In the research area, wheat is the main crop and Table 3.3 provides details of structure of wheat production cost.

Table 3.3 Wheat production cost structure

	Labor	Irrigation	Seed	Fertilizer	Pesticide	Machine	Total
Number of observations	317	317	317	317	317	317	317
Average costs (yuan/ton)	884.53	375.54	142.21	264.88	28.84	121.38	1817.37
Percentage share in total cost (%)	48.67	20.66	7.82	14.57	1.59	6.68	100.00

Source: Based on the field survey.

From the table, we know that labor cost account for the largest percent of the total production cost (48.67%). Another two important parts of the production cost are irrigation water and fertilizer costs, which account for 20.66% and 14.57% of the total cost, respectively. Besides, both the seed (7.82%) and machine cost (6.68%) account for less than 10% of the total cost. Among the six categories of costs, pesticide cost contributes least to the production cost, only 1.59%.

4. Model specification

The model estimated is based on the production cost model that was derived from a farm household model by Tan et al. (2008). According to Sadoulet (1995), the objective of the farm - household model is to maximize the utility function which is subject to budget and resource constraint. Therefore, we are able to derive the production cost in the situation of maximized utility. Tan et al. (2008) presents a production cost equation where the cost is the function of farm, household and village-specific characteristics.

Based on that study, this thesis incorporates a set of land fragmentation indicators and other factors of farm characteristics which directly influence the production costs. Besides, the model also includes farm, household characteristic and village-specific characteristics variables. Accordingly, the production cost function is specified as follows:

$$C = g(\zeta, \xi, v) \quad (1)$$

Where: C The production cost per unit product, ζ The farm characteristics variables, ξ The household characteristic variables, v The village-specific variables.

It is noted that the degree of land fragmentation is incorporated as one of the farm characteristics. Several indicators (e.g. Plot size & number, Simmons index, etc.) are employed or constructed to reflect the land fragmentation.

The model incorporates several most commonly used indicators (Tan et al., 2008) to measure the degree of land fragmentation: the number of plots and the average plot size. Alternatively, the model also employees two fragmentation indices introduced by Demetriou et al. (2013). They are constructed based on those two basic indicators, including Simmons Index (1964) and Januszewski Index (1968).

Simmons Index (SI)[8] is derived based on the number of plots owned by the single household, the size of a plot and the total holding size. The standard formula of SI, defined by Simmons (1964) is:

$$SI = \frac{\sum_{i=1}^{n} \alpha_i^2}{A^2} \quad (2)$$

Where: n The number of plots, α The plot size, A The the total holding size.

With the same factors, we can also obtain the Januszewski Index (JI).

$$JI = \frac{\sqrt{\sum_{i=1}^{n} \alpha_i^2}}{\sum_{i=1}^{n} \sqrt{\alpha_i}} \quad (3)$$

However, the data of individual plot size are not available in the dataset. Based on the survey outcome, the plots are classified by the land use type and grouped into 8 categories: (i) irrigated area, (ii) water use right area, (iii) dry and crop area, (iv) fruit tree area, (v) forest area, (vi) ecological forest, (vii) grassland area, (viii) ecological grassland.

In the agricultural production, plots can generally be used for more than just one crop, and wheat is the main crop in the research region. Therefore, the production costs caused by fragmentation are likely to affect all crops planted by a farmer. However, there is no information on the number of plots planted with wheat in the data set. For each household, we only know the plot size of each land use type & the number of the plots. Therefore, we decide to focus on the production costs of the main crop which is affected by the fragmentation of the whole farm. However, the dataset used is not good enough for measuring the Simpson Index which is derived

[8] SI = 1-Simpson Index(Tan et al., 2006 and Blarel et al., 1992)

based on th the individual plots size. In this thesis, we replace it by the average plot size of three land use types(irrigated area, water use right area and dryland crop area,)

Variables

In the model, the agricultural production costs cover the cost of labor, irrigation water, seed, chemical fertilizer, pesticides, machine use and the total cost. Each type of cost is the function of the variables from farm, household and village characteristics.

Next, descriptive statistics of the variables, and the expected impact of each indicator on wheat production cost are presented in the table 4.1 and 4.2.

Table 4.1 Descriptive statistics of variables

Variables	No. of obser-vations	Minimum	Maximum	Mean	Std. Dev.
Dependent variables					
Labor cost (Yuan/ton)	317	16.36	4127.27	884.53	592.84
Irrigation water cost (Yuan/ton)	317	24.6	1680	375.54	288.95
Seed cost (Yuan/ton)	317	20.83	882.35	142.21	95.8
Chemical fertilizer cost (Yuan/ton)	317	13.89	1950	264.88	274.3
Pesticide cost (Yuan/ton)	317	0.37	3200	28.84	182.59
Machine cost (Yuan/ton)	317	5.95	1661.54	121.38	149.49
Explanatory variables					
Farm size (Mu)	317	1.5	68	17.41	9.25
Average plot size (Mu)	317	0.29	5.6	1.47	0.77
Simmons Index	317	0.02	0.53	0.1	0.07
Januszewski Index	317	0.09	3.94	0.38	0.28
Land fertility (1=Good, 2=Medium and 3=Poor)	317	1	3	1.39	0.54
Land slope (1 = plains , 2 = slope and 3 = other)	317	1	2	1.04	0.19
Household size (number of household members: person)	317	1	11	4.39	1.38
Age of household head (Years)	317	21	74	45.99	10.2
Average age of household members (Years)	317	17	71	34.92	9.08
Education level of household head (Years)	317	1	16	7.21	2.62
Average education level of household members (Years)	317	2	17	7.21	2.15
Available savings (1=zero,2=<5000,3=5000-10000, 4=10000-20000, 5=20000-50000, 6=>50000)	317	1	6	1.58	1.2
Received credits (Yuan)	317	0	60000	6658	6038
Irrigation district dummies variable (1= village is located in Tongziba district ,0= otherwise)	317	0	1	0.24	0.43
Irrigation district dummies	317	0	1	0.22	0.41

variable (1= village is located in Daduma district, 0= otherwise)					
Irrigation district dummies variable (1= village is located in Suyoukou district, 0= otherwise)	317	0	1	0.06	0.24
Irrigation district dummies variable (1= village is located in Haichaoba district, 0= otherwise)	317	0	1	0.09	0.29

Source: Based on the field survey.

All the dependent variables and explanatory variables with expected signs are listed in the following table.

Table 4.2 Expected signs of explanatory variables

Explanatory variables	Expected sign
Farm characteristics	
Farm size (mu) (FS)	-
Fragmentation indicator(Simmons Index (SI)/ Januszewski Index (JI))	-/+
Land fertility (1=Good, 2=Medium and 3=Poor) (LF)	+
Land slope (1 = plains, 2 = slope, 3 = other) (LS)	+
Household characteristics	
Household size (number of household members: person) (HS)	-
Average age of household members (years) (AM)	-/+
Education level of household head (years) (EH)	-
Available savings (yuan) (1=zero, 2=<5000, 3=5000-10000, 4=10000-20000, 5=20000-50000, 6=>50000) (AS)	-
Received credits (yuan) (RE)	-
Village characteristics	
Irrigation district dummies variable, 1= village is located in Tongziba district (IA)	+
Irrigation district dummies variable, 1= village is located in Daduma district (IB)	+
Irrigation district dummies variable, 1= village is located in Suyoukou district (IC)	+
Irrigation district dummies variable, 1= village is located in Haichaoba district (ID)	+

The farm characteristic variables have direct impacts on the production efficiency and therefore affect the production costs. Farm size indicates the economies of scale effect, and larger farm size leads to a greater economies of scale effect, decreasing the production cost per unit output. The average plot size and another two indices are used to capture the effect of land fragmentation. With the fixed total farm size, the greater number of plots and smaller average plot size mean higher degree of fragmentation. The effects of plot size & number and another two indices are undetermined (Tan et al., 2008). They are commonly considered to increase the costs, because the spatially separated plots hinder the use of modern agricultural mechanization. Besides, the fragmented land brings about more difficult in the land management to the farmers. However, as argued before, the land fragmentation also contributes to the cost reduction by allocating labor force efficiently and smoothing disaster & marketing risk. In all, the effects of the number of plots and fragmentation indices are unpredictable. Besides, the land quality can also influence the cost, and it is reflected by two variables: land fertility and land slope of the wheat land. Given the same amount of inputs used, the fertile land normally gives more output than the barren land, and therefore decreases the production cost per unit output. The flatter land requires less irrigation water and it is easier to operate with animal traction or machines and therefore has lower production costs per unit output.[9]

Next, we move on to the household characteristics variables, which influence the household's adoption of the agriculture production technology. As a result, the production efficiency is affected and therefore the cost is influenced. In addition, the shadow price of labor of big household is lower than that in small households, because the large households are more likely to use their own family members instead of the hired labor than the small households (Tan et al., 2008). Besides, the age influences the cost from two sides. On the one hand, the aged labor has more experience in the agriculture production; on the other hand, their physical condition is not strong as young labor. So the effects of age of household head and the average age of household members are unknown. The higher education level helps farmers to adopt more advanced technology and scientific management method. Therefore, the lower cost results from the higher education level of household head and average education level of household members. In addition, the saving and received credits enrich the farmers who can invest and manage a more efficient way with the less budget constraint. We can conclude that the available savings and received credits can reduce the production cost.

Besides, the village-specific characteristic includes four irrigation district dummy variables. The irrigation district dummy variables reflect the irrigation environment. Because Hongshuihe irrigation system is more advanced than 4 irrigation systems (Tongziba, Daduma, Suyoukou, Haichaoba), the villages in Hongshuihe area apply relatively more high-tech agricultural technologies and therefore, the production cost is relatively lower.

Finally, because the researched area is lack of water and the irrigation water is important to the wheat production, we also estimate the interaction effect of irrigation district and land fragmentation indicator. In the same irrigation district, the higher land fragmentation indicator is expected to increase the production cost; furthermore, when SI increases by the same percent, the production cost of Hongshuihe district where the most advanced irrigation technologies are applied is expected to show the smallest increase. In Chapter 5, the estimation result will show the marginal effect of the Simmons Index in different irrigation districts on production cost per unit.

Functional form

The thesis formulates and estimates the production cost with an explicit focus on the measurement of land fragmentation. The estimation outcome concerns the effects of land fragmentation on each type of cost and the total cost. In addition, to examine marginal effect of SI in different irrigation district on the production cost per unit, we introduce the cross terms into the model.

Based on the above variables, we present two optional functional forms: linear and semi-log functional forms. To determine a function from, we will test the different functional forms for misspecification (Ramsey RESET test) and goodness of fit (R-squared, F-test). Besides, the ordinary least squares estimation (OLS) method is used for estimating the unknown coefficients. To ensure we obtain the unbiased and efficient estimator, we need to test the heteroscedasticity (Goldfeld-Quandt test & White test) and multicollinearity (Condition number test and Farrar–Glauber test). Besides, F-test and T-test are also incorporated to examine the Significance of the regression and the significance of variables.

Finally, the semi-log functional form (4) passes all the tests, therefore it is applied in our analysis. It is noted that the Simmons/Simpson Index is the most commoly used index(Tan et al., 2006 and

[9] Land fertility=Good and Land slope= are taken as the reference category.

Blarel et al., 1992), so the model employs Simmons Index as land fragmentation indicator.

$$\ln (PC_i) = \alpha_{0i} + \alpha_{1i} lnFS + \alpha_{2i} SI + \alpha_{3i} LF + \alpha_{4i} LS + \alpha_{5i} HS + \alpha_{6i} \mathrm{AM} + \alpha_{7i} AS + \alpha_{8i} RE + \alpha_{9i} EH + \alpha_{10i} IA + \alpha_{11i} IB + \alpha_{12i} IC + \alpha_{13i} ID + \alpha_{14i} IA * SI + \alpha_{15i} IB * SI + \alpha_{16i} IC * SI + \alpha_{17i} ID * SI + \sigma \quad (4)$$

Where:PC_i = Labor cost(LC), Irrigationwater cost (WC), Seed cost (SC), Fertilizer cost (FC), Pesticide cost (PC), Machine cost (MC)and Totalcost cost (TC), respectively; $\alpha_{1i} \dots \alpha_{17i}$ The unknown coefficients; All the explanatory variables are defined in Table 4.2; σ The disturbance term, i=1..317.

5. Regression results

In section 5.1, the estimation result is presented reflecting the effect of land fragmentation on the total production cost per unit. Then, the estimation results of cost categories are shown and analyzed in the section 5.2

5.1 Result for total production cost

Based on the estimation result, we know that the F-statistic of the equation which incorporates the total production cost as an independent variable is 3.15, high enough to reject the null hypothesis that all slope coefficients are zero. Therefore, we believe the difference of total wheat production cost among the households can be explained by the explanatory variables.

Table 5.1 Regression result for total cost

Explanatory variables	Coef.		t- Coef
Farm characteristics			
Farm size (mu)	-0.11281	*	-1.85
Simmons Index	0.434611		1.5
Land fertility (ref. = Good)			
Medium	0.027546		0.41
Poor	0.101628		0.53
Land slope=Slope (ref. = Plain)	-0.1499		-0.94
Household characteristics			
Household size (person)	0.004058		0.17
Average age of members (years)	-0.00209		-0.59
Average education level of household members (years)	-0.01833		-1.31
Available savings (yuan) (Ref. = no saving)			
<5000	0.284854	***	2.94
5000-10000	-0.03265		-0.24
10000-20000	0.048622		0.31
20000-50000	0.078917		0.48
>50000	-0.2592		-1.4
Received credits (yuan)	1.33E-05	***	2.74
Village characteristics			
Irrigation district			
Tongziba irrigation district	-0.02724		-0.16
Daduma irrigation district	0.660785	***	3.31
Suyoukou irrigation district	0.966743	***	3.05
Haichaoba irrigation district	0.319311		1.17
Interaction terms			
Simmons Index and Tongziba district	0.017349		1.14
Simmons Index and Daduma district	0.002581	**	2.22
Simmons Index and Suyoukou district	0.066035	**	2.18
Simmons Index and Haichaoba district	0.048171		0.3

Marginal effect of SI in different irrigation district

Constant	7.236523	24.74
R-squared	0.1982	
Adjusted R-squared	0.1352	
Number of observations	317	

Notes: Dependent variable (TC) and Farm size (FS) are in logarithm.

**Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*

Table 5.2 Marginal effect of Simmons Index in different irrigation districts

District	Coef.	t-statistic
Hongshuihe	0.4346	1.5
Tongziba	0.4519	0.98
Daduma	0.4372**	2.54
Suyoukou	0.5006***	2.8
Haichaoba	0.4828	1.56

*Notes: *Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*

Table 5.1 presents the estimated coefficients of all the explanatory variables. The result confirms the negative influence of farm size on the total production cost. We can expect a lower total production cost per unit output from the larger farm size. In detail, a 1% increase in farm size leads to 0.11% reduction in total wheat production cost.

Table 5.2 presents the marginal effect of Simmons Index on total production cost in the different irrigation districts. As a land fragmentation indicator, Simmons Index has a value of one for farms consisting of only one plot, while values close to zero mean a high degree of land fragmentation. Therefore, the positive coefficients of Simmons Index imply a high degree of fragmentation. According to the above tables, Simmons index does not significantly affects on the total production cost in three of thel five irrigation districts. In the villages using the Daduma and Suyoukou irrigation system, the Simmons Index shows significant influence on the total production cost per unit. In Daduma and Suyoukou districts, a 0.01 unit decrease in Simmons Index causes a 0.44% and 0.50% decrease in total cost respectively. Although the land fragmentation is supposed to lower the production efficiency from several perspectives, the empirical analysis indicates that in these two areas, the higher degree of land fragmentation causes a lower total cost per output in wheat production.

The other farm characteristic explanatory variables, however, do not show statistically significant influence on total production. Of the household characteristics, only available savings and received credits significantly affect the total production cost. The estimation result indicates the received credits are expected to increase the production cost and every 1 unit increase in received credit causes a 0.0013 % increase in total production cost. Besides, compared to the household without saving, in the household, which saves less than 5000 yuan, the saving shows a significant positive influence on the total production cost. It is clear that the estimation results of received credits and available savings do not support the corresponding anticipated sign listed in Table 4.2. There are two possible reasons which may explain the differences: (1) The households involvd in off-farm employment are generally richer and have more savings than households who work in agriculkture only. Therefore, the households with savings which is lower than 5000 yuan is richer than the households without saving, and they are more likely to work also outside agriculture.The non-agricultural activities may occupy the agriculture working time, increasing the agriculture production csot. (2) The capital usage efficiency is low in wheat production: In surveyed area, except for the wheat, the potato and barley are also the main crops. Therefore, the local households may invest the received credit into other crop production or outside agriculture and spend more time and energy on them. Therefore, a lower production efficiency can be expected in wheat production, leading to a higher cost.

To investigate the sensitivity of the total cost with respect to the choice of shadow wage rate, the model is simulated with 90% (37.14 yuan/day) and 50% (20.64 yuan/day) of the original shadow wage rate(41.27 yuan/day). And the regression results (Tables A.7 and A8) and conclusions are similar as above, reinforcing the conclusion drawn before.

The above analysis applies to the total production cost of wheat production. However, for each category of costs, the estimation results vary. In the agricultural production, households may substitute the one type input for another one in response to the change of production environment. Next, the estimation result of each production cost category is presented (Table 5.3) and analyzed.

5.2 Result of production cost category

Table 5.3 Regression result for each category of production cost

	Labor	Water	Seed	Fertilizer	Pesticide	Machine
Farm size	-0.1696*	-0.2472*	-0.1317**	0.1043	-0.1463	0.0099
Marginal effect of Simmons Index in different irrigation district						
Hongshuihe	-0.0435	0.6394	0.1832	1.0856**	1.9709**	1.0494**
Tongziba	0.0495	-0.3089	-0.0331	0.7036	1.9479**	0.9562
Daduma	0.4184	1.2093	0.3997	2.1841***	3.7376***	2.2675***
Suyoukou	0.7913	2.2787*	0.3855	2.3094***	3.9007***	3.1931***
Haichaoba	0.1566	1.6696	0.2955	1.3233*	2.5827**	1.2749

Notes: Table only presents the estimated coefficients of Farm size (FS) and Simmons Index (SI); Farm size is in logarithm; the estimation result of all the explanatory variables are shown in the Table A.6

**Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*

According to the table 5.2, the farm size shows significant negative influence on the labor, irrigation water and seed costs. It is noted that with a 1 % increase in the farm size, the labor cost per unit output decreases by 0.17%. The irrigation water and seed cost are expected to decline by 0.25% and 0.13%, respectively, when farm size increases by 1% size. The findings indicate that the larger farm size reinforces the economies of scale, by which the household is able to improve production efficiency of labor, irrigation and seed and therefore, causing lower costs per unit output.

For each cost category, the marginal effect of Simmons index shows big differences in the four irrigation districts. According to Table 5.3, the Simmons Index does not affect the labor and seed cost significantly. On the irrigation water cost, only in Suyoukou district, land fragmentation shows significant negative impact. A 2.3% decrease in irrigation cost is expected from a 0.01 unit decrease in the Simmons Index. Of all the cost categories, the pesticide cost is affected by the Simmons Index mostly. It is observed to be influenced by the land fragmentation in all five districts. Pesticide cost is affected mostly by land fragmentation in Suyoukou district, where a 0.01 unit decrease in Simmons Index causes a 3.7 % decrease in pesticide cost per unit. Furthermore, in the case of fertilizer and machine cost, the land fragmentation also shows a significant influence in Hongshuihe, Daduma and Suyoukou and, for fertilizer only, in Haichaoba district.

To analyze the sensitivity of the labor cost with respect to the choice of shadow wage rate, the shadow wage rate is fixed at 90% and 50% level, under which the model is estimated again.

Again, farm size is found to have a significant negative impact while the Simmons index has no significant impact on the labor cost (Tables A.7 and A.8, last column). Therefore, we can conclude that the conclusions for the labor cost are not sensitive to the choice of the shadow wage rate.

6. Conclusions and discussion

6.1 Conclusions

In this Chapter, the research questions are resumed and answered based on the result. The second, third and fourth questions have been answered in the previous chapter, so this section focuses on the rest of the questions.

What are the trends in land fragmentation in China and its main regions since the beginning of the 1980s?

Since 1980's, the size of farmland occupied by the household kept declining, and after 2003, it stayed at a same level. Besides, the number of plots held by the household showed a decreasing trend and the size of each plot kept increasing. In spite of the gradually increasing plot size, the small plots are the absolute majority in China. Moreover, the land fragmentation is most severe in the Western China, which had the largest number of plots and the smallest size of the plots. Further, although the number of small plots in Western China is higher than other two regions, land fragmentation declined rapidly in Western China, particularly when the SLCP was implemented.

What is the impact of land fragmentation and other factors in agricultural production costs in northwest China?

In this thesis, the land fragmentation is measured by farm size and Simmons index, which is derived based on the number of plots and plot size distribution. The estimation results show that higher degree of land fragmentation would decrease the total production cost per unit output in the wheat production in two of the five irrigation districts. Farm size is observed to decrease the total production cost. Simmons index is found to have no significant influence on the labor cost, indicating that the input of labor is expected to be unchanged on the change in land fragmentation. For the other cost categories, land fragmentation shows a negative influence on the production costs of fertilizer, pesticides and machines, although the impact differs between irrigation districts. Besides, it is concluded that the economies of scale are realized from the use of labor, fertilizer and seed, because the lower costs of them are observed in the case of higher farm size.

To what extent does land fragmentation and its impact on production costs differ between South and Northwest China?

Tan et al. (2008) analyzed the impact of land fragmentation on rice production cost in South China based on the 2001 survey data in Jiangxi Province. The researchers measured the land fragmentation by Simpson Index (1-Simmons Index), which is also derived based on the number of plots and plot size distribution. Besides, the average distance to plot and farm size are also incorporated in the analysis.

Similar as the conclusion of this thesis, their findings also confirm the negative influence of farm size on the total production cost per unit output. Further, the distance to plot is proved to have a negative impact on total production cost. However, due to the availability of the data, the influence of distance to plot on the production cost is not analyzed in this study. Moreover, Tan et al. (2008) found that the indicator of land fragmentation does not have a significant impact on the total production cost of rice. In contrast, the SI is proved to significantly affect total production cost per unit output of wheat in two irrigation districts of the research area.

The impact of land fragmentation on production cost category differs largely between South and Northwest China. In South China, the greater degree of land fragmentation leads to higher labor cost and lower fertilizer, seed and machine cost. This finding indicates that in the South region, when confronting the land fragmentation, the households substitute labor for other production inputs. Therefore, the labor-intensive method was applied to deal with the land fragmentation problems in South China. We find that land fragmentation negatively influences the total production cost per unit output in the two of the five irrigation districts in the research area in Northwest China. However, land fragmentation does not affect total cost per unit output in South China. In Northwest China, the labor cost is not influenced by the land fragmentation indicator but has a negative impact on the fertilizer, pesticide and machine costs, but not on irrigation water cost, in several irrigation districts. Hence, we can conclude that in the Northwest China, many households who are faced with a high degree of land fragmentation have lower fertilizer, pesticide, machine cost per unit output but do not have higher labor costs.

Compared to the South China, the Northwest region confronts the shortage of water, therefore, the irrigation water is important to the agriculture production. Compared to the model estimated for South China, the model in this thesis incorporates the irrigation system. Based on the estimation result, it is concluded that the production cost varies between the different irrigation districts in which different irrigation technologies are used.

6.2 Discussion

In this section, the restrictions of the thesis are reflected and several suggestions for the future research are provided.

The most commonly used land fragmentation indicator is number of plots, plot size and plot distance. The plot distance is expected to have a positive influence on the production cost per unit, because with the higher distance the travel time of the household increases, leading to a lower production efficiency (Tan et al., 2008). To provide a more explicit analysis of the land fragmentation, the effect of plot distance on the production might be simulated. In this thesis, the model employs the Simmons Index, which measures the degree of land fragmentation based on the plot size and plot number. However, the dataset used is not good enough for measuring the Simmons Index. The model includes the Simmons Index based on based on the average plot size instead of the individual plots size. Therefore, in the future study, the researchers might obtain the data on plot distance and individual plots sizes and incorporate it into the model.

One of the research question of this thesis to investigate the different of the impact of land fragmentation on production cost between South and Northwest China. In this thesis, the model is built based on the wheat production cost, the main crop in Gansu Province (Northwest China). However, in Jiangxi Province (South China), rice is the main crop and Tan et al. (2008) analyzed the effect of land fragmentation on rice production cost. Therefore, the impact might be different between regions, because different crops are grown (e.g. Per unit output of wheat needs less water than rice). In this thesis, the differences in results and conclusions are not analyzed from the crop type perspective. The future study might fill in this gap.

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Appendices

Table A.1 Three economic regions of China East,Center and West of China

East	Center	West
Liaoning Province	Heilongjiang Province	Shanxi Province
Hebei Province	Anhui Province	Gansu Province
Shandong Province	Inner Mongolia Autonomous Region	Qinghai Province
Jiangsu Province	Henan Province	Sichuan Province
Shanghai Province	Jiangxi Province	Yunnan Province
Zhejiang Province	Hubei Province	Guizhou Province
Fujian Province	Hunan Province	Tibet Province
Guangdong Province	Jilin Province	Ningxia Autonomous Region
Hainan Province	Shanxi Province	Xinjiang Autonomous Region
Guangxi Autonomous Region		
Beijing Municipalities		
Tianjin Municipalities		

Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Table A.2 Average area (Mu) per household, 1986-2009

	Country	Easter	Center	West
1986	9.2	6.35	11.92	9.74
1987	8.9	6.19	11.94	8.14
1988	9.32	5.93	11.82	9.98
1989	9.03	5.68	12.39	9.11
1990	7.98	5.83	9.78	8.51
1991	8.47	5.43	11.26	8.34
1993	8.07	4.9	10.49	9.08
1995	7.83	4.89	10.47	8.11
1996	7.78	4.8	10.63	7.85
1997	7.65	4.86	10.24	7.68
1998	7.76	4.96	10.39	7.57
1999	7.94	5.28	10.61	7.6
2000	7.44	4.06	10.23	7.28
2001	7.63	4.61	10.45	7.51
2002	7.56	4.5	11.06	6.57
2003	6.95	4.35	10.1	5.99
2004	7.34	4.41	10.91	6.02
2005	7.32	4.32	11.03	6
2006	7.32	4.23	11.02	5.89
2007	7.22	4.51	10.8	5.82
2008	7.16	4.3	10.74	5.93
2009	7.12	4.48	10.56	5.98

Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Table A.3 Average number of plots per household, 1986-2009

	Country	East	Center	West

1986	8.43	6.65	7.98	12.04
1987	8.37	6.48	7.94	12.49
1988	8.32	6.83	7.76	11.24
1989	7.93	6.59	6.78	11.50
1990	7.83	6.14	7.29	11.02
1991	8.22	5.95	7.23	12.99
1993	7.05	5.44	6.20	10.44
1995	6.47	4.78	5.84	9.76
1996	6.24	4.62	5.68	9.38
1997	6.12	4.45	5.52	9.27
1998	6.11	4.62	5.36	9.02
1999	6.06	4.45	5.31	9.36
2000	5.90	4.16	5.22	9.14
2001	5.75	3.94	5.16	8.86
2002	5.75	3.91	5.03	8.85
2003	4.91	3.51	4.76	6.75
2004	4.96	3.49	4.50	7.27
2005	4.79	3.35	4.46	6.84
2006	4.71	3.22	4.28	6.82
2007	4.44	3.20	4.20	6.19
2008	4.26	3.13	4.05	5.96
2009	4.10	3.78	3.83	4.96

Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Table A.4 Average area (Mu) per plot, 1986-2009

	Country	East	Center	West
1986	1.09	0.95	1.49	0.81
1987	1.06	0.96	1.50	0.65
1988	1.12	0.87	1.52	0.89
1989	1.14	0.86	1.83	0.79
1990	1.02	0.95	1.34	0.77
1991	1.03	0.91	1.56	0.64
1993	1.14	0.90	1.69	0.87
1995	1.21	1.02	1.79	0.83
1996	1.25	1.04	1.87	0.84
1997	1.25	1.09	1.86	0.83
1998	1.27	1.07	1.94	0.84
1999	1.31	1.19	2.00	0.81
2000	1.26	0.98	1.96	0.80
2001	1.33	1.17	2.03	0.85
2002	1.31	1.15	2.20	0.74
2003	1.42	1.24	2.12	0.89

2004	1.48	1.26	2.42	0.83
2005	1.53	1.29	2.47	0.88
2006	1.55	1.31	2.57	0.86
2007	1.63	1.41	2.57	0.94
2008	1.68	1.37	2.65	0.99
2009	1.74	1.19	2.76	1.21

Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Table A.5 Plot size distribution in China, 1993-2009

	mu	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	<1	5.03	4.58	4.42	4.26	4.28	4.25	4.15	4.01	4.07	3.16	3.15	3.03	2.94	2.72	2.55	2.41
Country	**1-3**	1.49	1.38	1.31	1.35	1.32	1.29	1.24	1.22	1.16	1.23	1.26	1.23	1.23	1.18	1.15	1.14
	>3	0.54	0.51	0.51	0.51	0.51	0.52	0.51	0.52	0.52	0.52	0.55	0.53	0.54	0.54	0.56	0.55
	<1	4.01	3.33	3.23	3.04	3.17	3.01	2.84	2.64	2.64	2.16	2.16	2.04	1.9	1.9	1.85	2.5
East	**1-3**	1.16	1.17	1.11	1.13	1.16	1.14	1.04	1.01	0.97	0.99	0.99	0.99	0.99	0.97	0.94	0.93
	>3	0.28	0.28	0.28	0.28	0.29	0.3	0.28	0.29	0.3	0.36	0.34	0.32	0.33	0.33	0.34	0.35
	<1	4	3.71	3.58	3.49	3.39	3.37	3.28	3.21	3.09	2.67	2.37	2.36	2.24	2.18	2.07	1.88
Center	**1-3**	1.43	1.34	1.29	1.25	1.21	1.19	1.16	1.16	1.09	1.28	1.27	1.25	1.19	1.17	1.12	1.11
	>3	0.78	0.79	0.81	0.78	0.76	0.75	0.78	0.79	0.85	0.81	0.86	0.85	0.85	0.85	0.86	0.86
	<1	7.87	7.62	7.36	7.09	6.89	7.23	7.09	6.86	7.02	4.93	5.34	5.02	4.95	4.36	4.08	3.07
West	**1-3**	2.04	1.7	1.61	1.78	1.68	1.64	1.62	1.6	1.47	1.45	1.57	1.48	1.53	1.44	1.46	1.5
	>3	0.53	0.44	0.41	0.4	0.45	0.49	0.43	0.41	0.36	0.37	0.36	0.34	0.34	0.39	0.42	0.41

Source: National Rural fixed observation point survey data compilation (1986-1999, 2000-2009)

Table A.6 Regression result of all the cost categories

	LC		WC		SC		FC		PC		MC	
Farm characteristics												
Ln(FS)	-0.1697	*	-0.2473	*	-0.1317	**	0.1043		-0.1463		0.0099	
SI	-0.0435		0.6394		0.1832		1.0856	**	1.9709	***	1.0494	**
LF												
LF =2	-0.0197		-0.0900		0.0134		0.2005	*	-0.0812		0.1071	
LF =3	0.0760		-0.2086		0.1543		0.3253		0.9998	**	0.5341	
LS												
LS =2	-0.3094		0.2070		-0.0731		-0.0550		-0.1044		-0.1342	
Household characteristics												
HS	0.0155		-0.1039	*	0.0059		0.0000		-0.0615		0.0209	
AM	-0.0039		-0.0007		0.0089	***	-0.0087		-0.0002		0.0009	
EM	-0.0041		-0.0182		-0.0106		-0.0464	**	-0.0790	**	-0.0415	
AS												
AS =2	0.3527	**	0.4235	*	-0.0255		0.2512		0.2752		0.3016	*
AS =3	0.1103		-0.6505	**	-0.1324		-0.1257		-0.0931		-0.1539	
AS =4	0.2354		-0.0287		-0.2223		-0.3656		-0.1477		-0.1152	
AS =5	-0.0130		0.0932		0.2530		0.0600		0.2334		0.1616	
AS =6	-0.2169		-0.3385		-0.2230		-0.4730		-0.1907		-0.3603	
RE	1.25E-05	*	1.42E-05		3.27E-06		1.12E-05		2.04E-05	*	3.23E-06	
Village characteristics												
IA	0.0930		-0.9483	**	-0.2163		-0.3820		-0.0230		-0.0932	
IB	0.4619		0.5700		0.2165		1.0985	***	1.7666		1.2182	***
IC	0.8348	*	1.6394	**	0.2024		1.2238	**	1.9297	***	2.1437	
ID	0.2001		1.0303		0.1123		0.2377		0.6118		0.2256	
Interaction terms												
SI*IA	0.093		-0.9483	**	-0.2163		-0.382		-0.023		-0.0932	
SI*IB	0.4619		0.5699		0.2165		1.0985	***	1.7667	**	1.2181	**

SI*IC	0.8348	1.6393	0.2023	1.2238	**	1.9298	*	2.1437	***
SI*ID	0.2001	1.0302	0.1123	0.2377		0.6118		0.2255	

Notes: Dependent variable and Farm size (FS) are in logarithm.

**Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*

Table A.7 Regression result at 90% shadow wage rate

	TC		LC	
Farm characteristics				
Ln(FS)	-0.1096	*	-0.1697	*
SI	0.4501	*	-0.0435	
LF				
LF=2	0.0305		-0.0197	
LF=3	0.1056		0.0760	
LS				
LS=2	-0.1454		-0.3094	
Household characteristics				
HS	0.0035		0.0155	
AM	-0.0020		-0.0039	
EM	-0.0191		-0.0041	
AS				
AS=2	0.2823	***	0.3527	**
AS=3	-0.0397		0.1103	
AS=4	0.0392		0.2354	
AS=5	0.0833		-0.0130	
AS=6	-0.2614		-0.2169	
RE	4.83e-06	***	6.88e-06	**
Village characteristics				
IA	-0.0394		0.0930	
IB	0.6683	***	0.4619	*
IC	0.9720	***	0.8348	*
ID	0.3223		0.2001	
Interaction terms				
SI*IA	0.0198		0.0871	
SI*IB	0.0027	**	0.3985	
SI*IC	0.0645	**	0.8984	
SI*ID	0.0398		0.2354	

Notes: Dependent variable and Farm size (FS) are in logarithm.

**Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*

Table A.8 Regression result at 50% shadow wage rate

	TC		LC	
Farm characteristics				
Ln(FS)	-0.0915	*	-0.1697	*
SI	0.5347	*	-0.0435	
LF				
LF=2	0.0480		-0.0197	
LF=3	0.1310		0.0760	
LS				
LS=2	-0.1228		-0.3094	
Household characteristics				
HS	0.0005		0.0155	
AM	-0.0017		-0.0039	
EM	-0.0232	*	-0.0041	
AS				
AS=2	0.2682	***	0.3527	**
AS=3	-0.0790		0.1103	
AS=4	-0.0131		0.2354	
AS=5	0.1074		-0.0130	
AS=6	-0.2756		-0.2169	
RE	4.74e-06	***	6.88e-06	**
Village characteristics				
IA	-0.1084		0.0930	
IB	0.7112	***	0.4619	
IC	1.0037	***	0.8348	*
ID	0.3350		0.2001	
Interaction terms				
SI*IA	0.0254		0.3863	
SI*IB	0.0048	**	-0.7697	
SI*IC	0.0679	**	-1.9603	
SI*ID	0.0452		0.8804	

Notes: Dependent variableand Farm size (FS) are in logarithm.

**Significant at 10% level, **Significant at 5% level and ***Significant at 1% level.*