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Lili Jia

Land fragmentation and off-farm labor supply in China

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ABSTRACT

This thesis focuses on testing whether land fragmentation in China has an impact on off-farm labor supply by utilizing a data set developed between 1995-2002 for the Zhejiang, Hubei and Yunnan Provinces of China. Adopting the institutional innovation theory and a microeconomic farm household model, the thesis contributes to improving the understanding of the current widespread phenomenon of land fragmentation in four aspects: the determinants of land fragmentation in China; a theoretical analysis of the effects of land fragmentation; estimating the effect of land fragmentation on agricultural labor productivity; and estimating the effect of land fragmentation on off-farm labor supply.

First, an institutional innovation theory is introduced to analyze the determinants of land fragmentation in China. We find that the current land institution, which leads to land fragmentation, has its roots in the demand for land decentralization from farmers, but is constrained by incomplete property rights. Therefore, land reallocation does not necessarily increase land fragmentation, and whether the land market can reduce land fragmentation or not depends on the development of the local labor market.

Second, the microeconomic farm household model is applied to aid in understanding the effects of land fragmentation on agricultural labor productivity and off-farm labor supply. The analysis shows that the effects of land fragmentation depend on the local shape of the production function. A positive effect of land fragmentation on agricultural labor productivity may increase the off-farm labor supply, while a negative effect suggests a decrease of off-farm labor supply, and the effect of off-farm labor supply may be neutral if the labor market is constrained.

Third, a test for the effect of land fragmentation on agricultural labor productivity is conducted, and the result shows that the land fragmentation decreases agricultural labor productivity in general, implying an adoption of land consolidation. But this effect is only obvious in the Zhejiang province, where the labor market is better developed.

Finally, a direct test for the effect of land fragmentation on off-farm labor supply is implemented. The findings indicate that the off-farm labor supply is not influenced by land fragmentation due to the constrained labor market, suggesting a need to further develop the labor market. Furthermore, the off-farm wage and educational levels play a role in increasing off-farm labor supply, while the land endowment intends to decrease it.

ZUSAMMENFASSUNG

Diese Arbeit behandelt die Frage, ob die Landfragmentierung in China einen Einfluss auf das außerlandwirtschaftliche Arbeitsangebot hat. Dazu werden Daten aus den chinesischen Provinzen Zhejiang, Hubei und Yunnan der Jahre 1995 bis 2002 herangezogen.

Unter Anwendung der Institutionellen Innovationstheorie und des mikroökonomischen Haushaltsmodells trägt diese Arbeit dazu bei, vier Aspekte der Landfragmentierung besser zu verstehen: Die Determinanten der Landfragmentierung in China, die theoretische Analyse der Effekte der Landfragmentierung, empirische Schätzung des Effektes der Landfragmentierung auf die landwirtschaftliche Arbeitsproduktivität und Betrachtung der Auswirkungen der Landfragmentierung auf das außerlandwirtschaftliche Arbeitsangebot.

Die gegenwärtigen Institutionen in der Landallokation, die zu dem hohen Grad der Landfragmentierung in China führen, haben ihre Wurzeln in der Nachfrage der Landwirte nach Landdezentralisierung. Problematisch hierbei sind die unvollständigen Eigentumsrechte. Aus diesem Grund steigert Landreallokation nicht notwendigerweise die Landfragmentierung. Die Frage, ob der Landmarkt Landfragmentierung reduzieren kann, hängt zudem von dem Entwicklungsstand des lokalen Arbeitmarktes ab.

Zuerst wird in die Institutionelle Innovationstheorie eingeführt, um die Determinanten der Landfragmentierung in China zu herauszuarbeiten.

In einem zweiten Schritt wird das mikroökonomische Haushaltsmodell für landwirtschaftliche Haushalte angewandt, um Erkenntnisse über die Effekte der Landfragmentierung auf landwirtschaftliche Arbeitsproduktivität und das außerlandwirtschaftliche Arbeitsangebot zu erlangen.

In den Analyseergebnissen kann gezeigt werden, dass die Effekte der Landfragmentierung von der Ausprägung der lokalen Produktionsfunktion abhängen. Eine positive Auswirkung der Landfragmentierung auf landwirtschaftliche Arbeitsproduktivität lässt das außerlandwirtschaftliche Arbeitsangebot der Haushalte steigen. Eine negative Auswirkung dagegen zeigt eine Verringerung des außerlandwirtschaftlichen Arbeitsangebotes. Neutrale Konsequenzen gehen von einem eingeschränkten Arbeitsmarkt aus.

An dritter Stelle wird ein Test mit dem Ziel durchgeführt, den Effekt der Landfragmentierung auf landwirtschaftliche Arbeitsproduktivität herauszufinden. Die Ergebnisse zeigen, dass die Landfragmentierung im Allgemeinen die landwirtschaftliche Arbeitsproduktivität reduziert, wenn man einen Landkonsolidierungsprozess

annimmt. Allerdings ist dieser Effekt nur für die Provinz Zhejiang eindeutig, wo der Arbeitsmarkt besser entwickelt ist.

Schließlich wird ein direkter Test des Einflusses von Landfragmentierung auf das außerlandwirtschaftliche Arbeitsangebot implementiert. Die gewonnenen Erkenntnisse deuten darauf hin, dass das außerlandwirtschaftliche Arbeitsangebot wegen des begrenzten Arbeitsmarktes nicht von der Landfragmentierung beeinflusst wird. Dies deutet darauf hin, dass eine Weiterentwicklung des Arbeitsmarktes unabdingbar ist. Außerdem spielen das außerlandwirtschaftliche Lohnniveau und das Bildungsniveau eine Rolle dabei, das außerlandwirtschaftliche Arbeitsangebot zu vergrößern, wogegen eine ausreichende Ausstattung mit Land es eher verringert.

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LIST OF ABBREVIATION

2SLS	Two-stage Least Square
CD	Cobb-Douglas
CEECs	Central and Eastern European Countries
CI	Confidence Interval
DID	Difference In Difference
FE	Fixed Effects
GDP	Gross Domestic Product
HRS	Household Responsibility System
i.i.d.	identically and independently distributed
IMR	Inverse Mills Ratio
IQR	Interquartile Range
IVs	Instrumental Variables
MPL	Marginal Productivity of Labor
OECD	Organization for Co-operation and Development
OLS	Ordinary Least Squares
PRC	People's Republic of China
RCRE in China	Research Centre for Rural Economy, Ministry of Agriculture
RE	Random Effects
RLCL	Rural Land Contracting Law
TVEs	Township and Village Enterprises

1 INTRODUCTION

As China recovers from the global economic crisis, the "migrant shortage" has become prominent in many coastal areas such as the Pearl River and Yangtze River deltas, leading employers to offer increased wages as they compete for employees (CHINA DAILY, 11 March, 2010). The number of peasant workers in the eastern areas of China accounts for around two-thirds of the total peasant worker decreases, that is, 8.9 % in 2009 due to a sharp decline of 8.9 million employees (NATIONAL BUREAU OF STATISTICS, 2010). The labor shortage in cities is just now challenging the widespread phenomenon of fragmented farm structure, which consumes many laborers in rural areas.

The small-scale farm, comprised of several disjointed parcels, indeed contributed to agricultural growth and equalitarianism during the early period of land decentralization (BRANDT, 2004; KUNG, 1994; LIN, 1992). On the other hand, an enlargement of farm size might not contribute to promoting labor productivity, since economies of scale could not be found in rural China due to the imperfections of factor markets (FAN, 2005; WAN and CHENG, 2001). However, with the development of the labor market, land fragmentation has been criticized as being a waste of laborers, as well as for increasing labor costs in China (TAN et al., 2008; WAN and CHENG, 2001). Hence, the farms' structural transformation exclusively points to the serious land fragmentation present in China. Whether land consolidation should be implemented tops the Chinese agricultural reform agenda.

This monograph will focus on this issue and provide insights into the effects of land fragmentation in the presence of incomplete factor markets. Our argument is that land consolidation may increase agricultural labor productivity and on-farm labor input, but fail to influence off-farm labor supply when the local labor market is constrained.

Our research contributes to the present land fragmentation studies in three ways. First, we provide an embedded investigation on the determinants of land fragmentation in China. Second, we theoretically analyze and empirically measure the effect of land fragmentation on agricultural labor productivity. Third, we directly estimate the effect of land fragmentation on off-farm labor supply.

There are four sections in this chapter. We start with the definition of land fragmentation, then we synthesize the debates concerning the effects of land fragmentation and lay out the challenging issues accordingly. In the final section, we provide an overview of the whole monograph.

1.1 Definition of land fragmentation

Land fragmentation is a common phenomenon in many transition countries, which has been investigated by extensive studies. BINNS (1950, p. 5) defined land fragmentation as the division of a single farm into several separate, distinct parcels (BENTLEY, 1987), while JACOBY (1971, p. 265) elaborated land fragmentation as "a division of land into small farms." Regarding land fragmentation in Eastern Europe, SABATES-WHEELER (2002) provided multi-dimensional definitions of fragmentation in her research and distinguished land fragmentation into four types. The first type is physical fragmentation, where non-contiguous land parcels are very small and distant from the owner's homestead. The second type is social fragmentation with respect to the mismatch between the people who have gained ownership and the ones who actually use the land. The third type is the activity fragmentation embedded in the mismatch between input factors, such as labor and equipment for farming and land usage. The fourth type is ownership fragmentation, which refers to the separation between legal and physical property rights, where the collectives have distributed ownership without specifying the exact location of the parcel.

In this monograph we carry out an in-depth study on the effects of land fragmentation with respect to small-scale farms in China, as well as in many transition countries in general. To avoid the institutional particularities of the other types of land fragmentations due to reforms in some countries, we adopt a more general definition of land fragmentation, which is the existence of a number of spatially separate plots of land that are planted as single units (MCPHERSON, 1982).

1.2 A synthesis of debates on the effects of land fragmentation

A great deal of previous research has studied the impact of land fragmentation on agricultural production and efficiency. However, the results are quite controversial and it is still uncertain whether land consolidation should be adopted or not. For instance, FLEISHER and LIU (1992) employed a Cobb-Douglas (CD) function and estimated the effect of number of plots on agricultural production by using household level data in Jilin, Jiangsu, Hebei, Henan and Jiangxi in China. These researchers found that the negative relationship between land fragmentation and aggregate agricultural production was still obvious after controlling for geographical characteristics and disasters, and argued that if the average number of plots and the number of crops were both reduced to one, total factor productivity would increase by 16 %.

The negative impact of land fragmentation is also supported by BIZIMANA et al. (2004), who found that land fragmentation indeed hindered the development of economies of scale in Southern Rwanda. HUNG et al. (2007) draw a similar conclusion after investigating land fragmentation in Vietnam. Recently, KAWASAKI (2010) has provided evidence that the costs of land fragmentation in agricultural production were greater than the benefits of those in Japan, and increased with an increase of farm size. However, none of these studies were applied in the presence of incomplete factor markets such as those presently observed in many transition countries. For example, when rural laborers have few opportunities to participate in off-farm work and agricultural income plays a crucial role for most farmers, the output loss resulting from equal land allocation might be modest for farmers compared with free market allocation, as proposed by BERCK and LEVY (1986).

NGUYEN et al. (1996) used updated data and estimated the effect of land fragmentation on agricultural productivity with a CD frontier function for major grain crops. They indicated that an increase of the plot size generally contributed to an increase of output in China. Further results showed that the positive relationship between plot size and yield was only significant when the plot size was smaller than a certain size for maize and wheat, but this relationship was not obvious for rice. However, the CD function does not allow elasticities of inputs to be varied, and a more flexible production function was estimated later by WAN and CHENG (2001). These authors focused on estimating the economies of scale and the effect of land fragmentation on agricultural production with a translog production function, and the results revealed that land fragmentation reduced output for grain products, and economies of scale were not obvious in China. In light of this, land consolidation was suggested instead of enlarging land, since economics of scale did not exist. The authors also predicted that an increase in average farm scale by 10 % would turn 60 million rural inhabitants towards non-farming sectors. However, the forecast based on production function does not take into account the development of the labor market in the sense that the rural laborers may not transfer out successfully if the labor market could not provide enough off-farm opportunities.

So the negative effect of land fragmentation on agricultural production may not hold when the factor markets are underdeveloped. MCCLOSKEY (1976) has proved that land fragmentation reduced risks in the absence of crop insurance in rural areas. FENOALTEA (1976) argued that medieval farmers did not reduce risks through land fragmentation, but saved labor purchase transaction costs through the spatial dispersion of plots. Land owners employed only a small number of successive employers in order to reduce the negotiation costs of employing laborers, because the labor market was encumbered and the transaction costs associated with employing new laborers were not negligible. This means that land fragmentation can help farmers avoid labor demand peaks and make it more convenient to organize a small number of employees. BLAREL et al. (1992) also estimated that land fragmentation could help local farmers reduce risks and overcome seasonal labor bottlenecks due to inefficiencies in land, labor, credit and food markets in Ghana and Rwanda. Thus, land consolidation is not necessary, though it may increase land productivity.

In his survey, BENTLEY (1990) also proved that farmers in Portugal were reluctant to put all of their land in one place since land fragmentation was not detrimental to farm production, while land consolidation might only benefit the rich farmers. Recent research on the land fragmentation effects in China was carried out by CHEN et al. (2009), who found that land fragmentation decreased technical efficiency in general, but an increase of the number of plots led to an increase of technical efficiency.

It has been pointed out that land fragmentation did not affect total production costs per unit of output, but resulted in more labor input rather than capital input (TAN et al., 2008). Lacking off-farm work opportunities, farmers with more and smaller plots intended to use more labor and less modern technologies compared to their counterparts with less and larger plots. Therefore, it is still unclear what kind of effects land fragmentation has on agricultural production.

Furthermore, if land fragmentation leads to an increase of agricultural productivity, it may increase agricultural supply as well, yet it may reduce the off-farm labor supply through labor market development. Thereby, land consolidation may release more labor surplus and contribute to the labor shortage in Chinese cities. Until now, no studies have focused on the effect of land fragmentation on off-farm labor supply. Our study tackles the puzzle concerning the effect of land fragmentation on agricultural production, and detects the effect of land fragmentation on off-farm labor supply.

1.3 Challenging issues and overview of monograph

We now unveil the challenging issues present in the current study of land fragmentation. The remaining chapters of the monograph are given over to three major tasks:

The first task is to identify the determinants of land fragmentation in China. The root of land fragmentation has been a heated topic for a long time, whereas very few studies have explored the case of China, which is one of the countries with the most serious land fragmentation. It is still not clear whether land fragmentation in China is driven by supply or demand side forces. Further, what kind of effect does the land market have on land fragmentation?

The second task is to estimate the effect of land fragmentation on agricultural labor productivity. How does land fragmentation affect agricultural labor productivity? Will land consolidation benefit all farmers?

The third task concerns the effect of land fragmentation on off-farm labor supply. How does land fragmentation affect off-farm labor supply? Does land consolidation necessarily lead to an increase of off-farm labor supply?

This monograph aims to address these problems. We adopt data from China, where the small-scale fragmented farms occur nationally and attempt to contribute to the heated debates over the effects of land fragmentation. The monograph is comprised of the following eight chapters.

Chapter 2 extends an investigation of the determinants of land fragmentation in China. This chapter synthesizes existing research concerning the determinants of land fragmentation and generalizes a theoretical model in order to analyze the determinants of current land fragmentation in China, as well as the effect of the land market on land fragmentation.

Chapter 3 provides a theoretical analysis of how land fragmentation affects agricultural labor productivity and off-farm labor supply. Further, a numerical simulation is illustrated to exemplify that the effects of land fragmentation are not known *a priori*. This chapter also lays out the theoretical scenarios for empirical studies concerning the effects of land fragmentation.

In chapter 4, a series of methodological challenges are illustrated and the corresponding strategies to solve these problems are presented. Moreover, it discusses some general methodologies to estimate functions with panel data and also prepares a foundation for the discussion in the empirical study chapters.

Chapter 5 introduces our research region, database and related data cleaning issues. This chapter supplies general information for our research regions regarding the development of agriculture, farm structure and labor market development. On the other hand, the source of the database and how to clean the data, in our estimation, are also clarified. An introduction to the research regions in our database will also help clarify the findings in next two chapters, as well as the discussion chapter afterwards.

How land fragmentation affects agricultural labor productivity is estimated in chapter 6. This chapter explores the testing of our theoretical scenarios directly via empirical methodologies. An unbiased estimation of the fixed effects of a translog production function is discussed. This technique is also applicable to the other panel data models with interaction terms.

Chapter 7 discusses estimates of the effect of land fragmentation on off-farm labor supply. A survey of how to estimate panel data models with sample selection bias and endogeneity has been investigated, which contributes to an unbiased estimation of off-farm labor supply function.

In chapter 8, we discuss our findings from previous chapters and further explore our theoretical and empirical studies. This chapter will address the key arguments of the whole monograph, as well as the current debates concerning land consolidation and land reform policies. Future land reform policies in China are also suggested.

Chapter 9 draws conclusions and brings an end to the monograph.

2 THE DETERMINANTS OF LAND FRAGMENTATION IN CHINA

Many studies have explored the determinants of land fragmentation and various explanations have been found for different countries (SARGENT, 1952; FENOALTEA, 1976; BENTLEY, 1990; SWINNEN, 1997). On the other hand, few researchers have focused on this issue in China except for TAN et al. (2006), who argued that the egalitarian principles of current institutions for distributing and reallocating land were the main reasons for land fragmentation, which implies supply-side driving forces. However, it has been found that decollectivization in China was a bottom-up institutional change (LIN, 1988; ROZELLE and SWINNEN, 2004), implying demand side driving forces. This contradiction pertains to debates on the driving forces of land fragmentation and suggests that further research on this topic is required before investigating the effects of land fragmentation.

This section will contribute to solving the puzzle presented above. The hypothesis is that land fragmentation in China comes from supply side driving forces. In the following, we start from a literature review to build a theoretical framework, then adapt the theory to analyze the case in China, further investigating the impact of the development of the land market on land fragmentation.

2.1 Driving forces of land fragmentation

The causes of land fragmentation have been one of the most widely discussed agricultural issues for years, and researchers have provided different explanations concerning how land fragmentation emerged and has become a widespread phenomenon. This section provides an overview of driving forces in order to lay out the analytical basis for investigating the determinants of land fragmentation in China.

In a study on the determinants of land fragmentation, BLAREL et al. (1992) classified them into two groups: supply side and demand side driving forces. The supply side driving forces indicate that the land is fragmented due to institutional reasons or laws, while the demand side driving forces refer to voluntary land fragmentation due to famers' production needs.

2.1.1 The supply side of driving forces

Inheritance

On the *supply* side, SARGENT (1952) traced the causes of land fragmentation in France by using a qualitative method, and found that land fragmentation was raised by the domestic inheritance system. According to French law, land should be equally divided among all the heirs[1]. Thus, a large farm was broken up and

[1] Code Civil, Articles 826, 831, 832. This basic law was adopted in 1803.

fragmented (SARGENT, 1952). However, farmers on large farms in Northwest Portugal could avoid land fragmentation by adopting a different inheritance system, which required bequeathing the whole farm to one child who married into the house, so called *casar-se para a casa*, who then paid all the other co-heirs in cash (BENTLEY, 1990).

Demographic change

When coupled with a partial inheritance system, a high population density may reinforce land fragmentation (BENTLEY, 1987; DIJK, 2003). Highly fragmented land was linked to population growth in the twelfth or thirteenth century in Europe when land became scarce (BENTLEY, 1987).

Land reform

Land fragmentation in most Central and Eastern European Countries (CEECs) is to a large extent considered to stem from the various systems of land reform embarked on after the collapse of the former Soviet Union. Collective and state farms, which were built after World War II by forcing private farmers and landowners to bring their land and other assets into a collectively organized production unit in consideration of scale economies and efficiency improvements, had to be privatized at the beginning of the 1990s (MATHIJS, 1997, p. 39; SWINNEN, 2000; THOMAS, 2006). Therefore, land fragmentation came from supply side land reform throughout the CEECs, as shown in Table 2-1.

In most CEECs, many collective farmlands were restituted to former owners, creating a large group of land-owners (SWINNEN, 1997, p. 364); large farms were fragmented in this process of decollectivization. In Bulgaria, arable land was restored to its original land owners as a result of land reform after World War II, which directly gave rise to land fragmentation. Some owners had several heirs and land had to be equally allocated to each of them, which led to further fragmentation (DIRIMANOVA, 2008, p. 33). On the other hand, the state provided land to landless families, which also contributed to an increase of land fragmentation (YANAKIEVA, 2001; DIRIMANOVA, 2008, p. 34). In 2001, there were 8 million plots in Bulgaria that were allocated for 1.8 million farms, with the average plot size amounting to 0.52 hectares (DIRIMANOVA, 2008, p. 34).

The Albanian government adopted a different land reform system by redistributing land to the rural population "on an equal per capita basis" (SWINNEN, 2000), which ended up with 2.3 million parcels for 0.7 million hectares (KODDERITZSCH, 1999, p. 33; SIKOR et al., 2009).

Romania implemented a combined procedure by imposing a limitation on the amount of land restitution and distributing the remaining share of its collective farmland to poor collective farm workers (LERMAN, 1999; SWINNEN, 2000); invariably, Romanian farmland was fragmented. According to the Organisation for Economic Co-operation and Development (OECD, 1993), there were 3.13 million private plots in Romania in 1993, where 4.7 million people received 9.4 million hectares, resulting in an average ownership size of 2 hectares.

In Hungary, a compound land policy was adopted. Private land was restituted to its owners, while part of the collective farm was compensated via auctions, and the rest was distributed among collective farm employees (SWINNEN, 1997, p. 367). Former owners who claimed to be compensated could obtain vouchers, which they could either invest into any land in the country through auction, or purchase other non-land assets (MATHIJS, 1997, p. 238; DIRIMANOVA, 2008, p. 30). At the end, 1.8 million new owners were provided with 2.6 million plots (BIRO et al., 2002). From the examples above, we learn that the current phenomenon of land fragmentation witnessed in many CEECs has been largely driven by the supply side of institutional innovation – that is, the land reforms in the process of privatization in the 1990s.

Table 2-1: Most important land reform procedures in CEECs

	Collective farmland		**State farmland**	
	Procedure	**% of TAL**	**Procedure**	**% of TAL**
Albania	Distribution (physical)	76	Distribution (physical)	24
Bulgaria	Restitution	72	Miscellaneous	9
Czech Republic	Restitution	61	Sale (leasing)	25
East Germany	Restitution	82	Sale (leasing)	7
Hungary	Restitution + distribution (phys.)+ sale for compensation bonds	70	Sale for compensation bonds+ sale (leasing)	12
Latvia	Restitution	57	Restitution	38
Lithuania	Restitution	62	Restitution	30
Poland	–	4	Sale (leasing)	19
Romania	Restitution + distribution (phys.)	58	Undecidede + Restitution	28
Russia	Distribution in shares	40	Distribution in shares	58
Slovakia	Restitution	71	Sale (leasing)	15
Slovenia	–	0	Restitution	17
Ukraine	Distribution in shares	n.a.	Distribution in shares	n.a.

Source: SWINNEN (2000).

Incomplete land market

A land market may also account for land fragmentation when it is poorly developed or land consolidation is restricted by the law (BLAREL et al., 1992). Even if a land market exists, farmers may still have the problem of fragmented landholdings because the land market itself is highly fragmented and imperfect, and can only provide small plots of land (SARGENT, 1952; BLAREL et al., 1992). In many CEECs, land markets are impeded by the huge number of smallholders who do not want to sell land since it can serve as a symbol of security when the market economy is unstable and inflation threatens the real value of financial wealth (SCHULZE, 2000; DIJK, 2003).

2.1.2 The demand side of driving forces

Risk aversion

Land fragmentation, on the other hand, may also come from farmers' *demand* due to incomplete factor markets. MCCLOSKEY (1976) first studied risk aversion effects using a quantitative method by comparing the coefficients of income variation on scattered and consolidated farms in mid-thirteen century England and found that the medieval English peasants scattered their land to insure themselves against natural disasters. Identical results were also found by HESTON and KUMAR (1983), who qualitatively analyzed cases in south Asian countries and concluded that local farmers preferred land fragmentation to reduce natural risks. In the absence of an agricultural insurance market, farmers may voluntarily choose land fragmentation as a risk reducing device by planting different crops suitable for different soil types (BLAREL et al., 1992; CARTER, 1997).

Labor buffer

When the labor market is absent, land fragmentation may smooth labor demand during the peak season and help farmers to overcome seasonal bottlenecks (HESTON and KUMAR, 1983; BLAREL et al., 1992). In another study of medieval England, FENOALTEA (1976) found that land fragmentation helped farmers in England overcome seasonal labor bottlenecks either by making good use of family members or employing fewer employees to decrease the transaction costs of purchasing or exchanging them. The transaction costs related to supervision and negotiation are thus reduced by employing only a small group of employees (FENOALTEA, 1976). When a reduction of transaction costs exceeds the costs of inefficiency, farmers exhibit a demand for more than one plot, indicating that land is fragmented.

An examination of previous studies reveals that land fragmentation is driven by two dimensional forces, as generalized in Table 2-2. An institutional setting from political entrepreneurs may result in land fragmentation; however, farmers may also need fragmented land in incomplete factor markets when a reduction of transaction costs in the markets exceeds the cost of inefficiency. Based on this framework, we next provide motivation for the research on the determinants of land fragmentation in China.

Table 2-2: Determinants of land fragmentation

Category	*Authors*	*Research region*	*Determinant*
Supply side	SARGENT (1952)	France	Compulsory crop rotation; inheritance; land market
	DIJK (2003)	Central Europe	Population; agricultural policy
	SWINNEN (1997)	CEECs	Land reform
Demand side	MCCLOSKEY (1976)	Medieval England	Risk aversion
	HESTON and KUMAR (1983)	India, Pakistan, and Sri Lanka	Risk aversion
	FENOALTEA (1976)	Medieval England	Transaction costs reduction of purchasing or exchanging labor
	BENTLEY (1990)	Northwest Portugal	Labor buffer effect

Source: Author's compilation.

2.2 The emergence of land fragmentation in China

Farm structure is always tied to the prevailing land institution; land reform thus plays an important role in the determinations of land fragmentation. In the discourse of New Institutional Economics, an institutional innovation, no longer regarded as exogenous, could be driven by either supply side or demand side forces (HAYAMI and RUTTAN, 1985, p. 93-110). These authors proposed that political entrepreneurs would supply institutional innovation, "… if the expected return from the innovation that accrues to the political entrepreneurs exceeds the marginal cost of mobilizing the resources necessary," (HAYAMI and RUTTAN, 1985, p. 107) while the demand for institutional innovation can be satisfied by either internal or external institutional changes. Following this line of reasoning, land fragmentation could originate from either the supply side or demand side. TAN et al. (2006) first investigated the causes of current land fragmentation in China and argued that the current land institution, created for the purpose of egalitarianism and land reallocation, were responsible for land fragmentation indicating a supply side driving force. Instead of targeting the current land fragmentation directly like TAN et al. (2006), we will map a general picture in this monograph to better understand the determinants of land fragmentation.

This section focuses on three periods of farm structure related to two main land reforms, which starts with historical land fragmentation serving as a horizontal scenario, then introduces two shocks in terms of land reforms. Special attention will be paid to the second reform, which directly results in the current land fragmentation, and a theoretical model will be constructed to gain insight into its underlying reasons.

2.2.1 Land fragmentation in history

The phenomenon of land fragmentation was observed a long time ago in China, as documented by many historical materials. One of the outstanding books is titled "Land utilization in China" by BUCK (1964), who initiated the study of agricultural economics in China within a neoclassical economic framework. In his book, BUCK (1964) provided a comprehensive economic analysis on land use and reported a large number of first-hand agricultural farm data obtained from an extensive survey covering 16,786 farms in 168 localities of 22 provinces from 1929-1933. Buck's study provides us with an opportunity to visit land fragmentation in a historical context, which elicits a good basis of understanding current farm structure characteristics.

BUCK's (1964) survey revealed that land fragmentation obviously occurred in most rural areas. As shown in Table 2-3, more than 60 % of farms had between 1-5 plots, and around one-fifth of the farms had more than 5 plots; ultimately, each farm owned 5.6 plots on average (Table 2-4), which indicated that land fragmentation was already a widespread phenomenon before the establishment of the People's Republic of China (PRC). However, rice regions were more fragmented than wheat regions, probably due to the higher population density in rice regions. Sometimes the plots were quite scattered and the average distance of the plots furthest from the homestead was nearly twice that of all plots to homestead (Table 2-4). It was also observed that the transaction cost of land fragmentation in wheat regions was higher than rice regions due to a longer average distance of all plots to homestead.

Table 2-3: Percentage of farms with a specific number of plots

Number of plots	*1-5*	*6-10*	*11-15*	*16-20*	*21-25*	*26-30*	*>31*	*Unknown*
China	67	22	5	2	1	1	1	1
Wheat region	65	23	6	3	1	1	1	*
Rice region	69	20	5	2	1	1	1	1
Wheat region area								
Spring wheat	73	18	5	2	*	1	1	1
Winter wheat-millet	66	25	5	2	1	1	1	0
Winter wheat-kaoliang	63	24	7	3	1	1	1	*
Rice Rregion areas								
Yangtze rice-wheat	67	21	6	2	1	1	1	1
Rice-tea	62	25	6	3	1	*	1	2
Szechwan rice	82	6	2	2	1	1	6	*
Double cropping rice	66	24	6	3	1	*	*	*
Southwestern rice	84	13	2	1	*	*	*	*

Source: 16,786 farms, 22 provinces, China, 1929-1933 (BUCK, 1964, p. 183).

Table 2-4: Degree of land fragmentation in the Republic of China

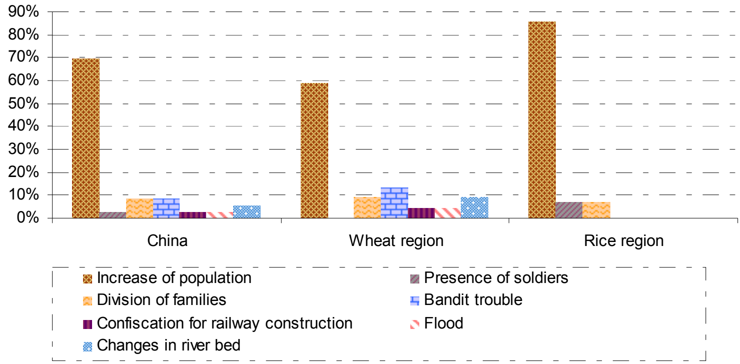
	Number of plots per farm	*Number of fields per farm*	*Average distance of furthest plots to homestead (meters)*	*Average distance of all plots to home-stead (meters)*	*Average size of plots (mu[2])*	*Average size of fields (mu)*
China	5.6	11.6	1,126.5	643.7	5.7	3.0
Wheat region	5.7	8.5	1,287.4	804.7	7.0	5.0
Rice region	5.5	14	965.6	482.8	4.8	1.5
Wheat region area						
Spring wheat	4.8	9.3	1,770.2	965.6	13.8	7.6
Winter wheat-millet	5.5	8.7	1,448.4	965.6	4.5	3.2
Winter wheat-kaoliang	6.2	8.2	1,126.5	643.7	6.0	5.0
Rice Rregion areas						
Yangtze rice-wheat	5.3	10.4	643.7	321.9	6.1	2.2
Rice-tea	5.4	14.1	1,126.5	643.7	2.7	1.0
Szechwan rice	9.7	23.7	482.8	321.9	8.3	1.2
Double crop-ping rice	5.4	13.4	1,287.4	643.7	3.5	1.5
Southwestern rice	3.7	18.4	965.6	643.7	3.9	0.7

Source: 16,786 farms, 22 provinces, China, 1929-1933 (BUCK, 1964, p.183).

Concerning the reasons of land fragmentation, the local data documented the changes of farm size from 1870 to 1933, and a series of reasons were generalized as depicted in Figure 2-1 and Figure 2-2. A decrease of farm size was mostly attributed to an increase in population, and following inheritance or bandit trouble, accounted for less than 15 %. On the other hand, an increase of farm size mostly came from the use of uncultivated land and a decrease in population. So the change of land/labor density was mainly a product of the change in the degree of land fragmentation. It was revealed that land was often sold by cutting it into small plots because the land owners could not afford a large plot, but were reluctant to lose any plots once they were obtained (TAN et al., 2006).

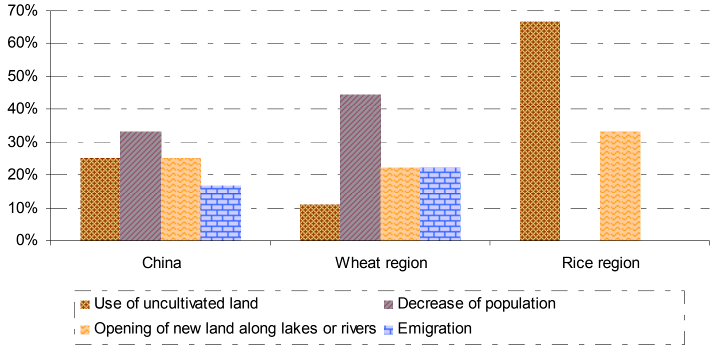
[2] 15 mu=1 hectare.

Figure 2-1: Reasons of farm size decrease



Source: Local statistics adapted from BUCK (1964, p. 182).

Figure 2-2: Reasons of farm size increase



Source: Local statistics adapted from BUCK (1964, p. 182).

However, little information was known with respect to the demand side reasons of land fragmentation, since all of the causes BUCK (1964) provided were from the supply side. Interestingly, BUCK (1964) not only reported the number of plots, but also the number of fields per farm (Table 2-3), with the latter being almost twice that of the former, indicating that farmers usually planted several crops on one plot. A larger number of fields may be due to double cropping, especially in rice regions, which are more likely to plant crops more often than one growing season, and the average index of double cropping in rice regions is 166 % (BUCK, 1964, p. 216). However, double cropping is not enough to explain this phenomenon since there are more than 2 crops per plot on average in many regions, for example southern rice (see Table 2-4). So it is reasonable to believe that farmers prefer crop diversification, particularly as it was documented that the varieties of individual crops were numerous (HOKEN, 2010; BUCK, 1964, p. 221). Given the traditions of feudal society, farmers at that time targeted self-sufficient agricultural production, and a certain degree of cropping varieties was necessary either for self-consumption or for sustaining the agricultural production of the next year. Therefore, farmers might accept more than one plot for the convenience of crop diversification, and a fragmented farm structure provided farmers more opportunities to diversify crops (WU et al., 2005).

In brief, the land fragmentation phenomenon was common in the history of China, and was mainly dominated by supply side driving forces such as population growth. However, a number of self-sufficient farmers might have benefitted from it due to its advantage of crop diversification in underdeveloped agricultural input factor and product markets. Leaving behind a long history of feudal society, Chinese farmers still pursued a traditional system of agricultural production and operation in the Republic of China[3] (1912-1949), and small self-sufficient farms were still found in rural areas since the change of governance did not radically pertain to a change of prevailing land institutions in rural areas. Soon after the establishment of PRC, land fragmentation was extinguished through nationwide land reform (land collectivization), but reappeared in the next reform after 1978. So what are the driving forces behind this? Next, we will address this issue and lay out a theoretical model to analyze the emergence of the current type of land fragmentation.

2.2.2 The emergence of land fragmentation in PRC

TAN et al. (2006) proposed that land fragmentation in China was mainly determined by the current land institutional system – Household Responsibility System (HRS) – implying supply side-driven forces. However, HRS was considered to be a bottom-up rather than a top-down institutional innovation, indicating demand side driving forces, which contradicts the argument of TAN et al. (2006). Thus, the cause of land fragmentation in China again becomes a puzzle.

Following the collective movement, which was totally driven by the representatives of government such as local party cadres and central leaders (NOLAN, 1988, p. 48), most agricultural farms in China have been organized under the production team system since 1955 (ROZELLE and SWINNEN, 2004; MEISNER, 1999, p. 131). Private plots were abolished and labor was paid "according to need" instead of "according to work" (NOLAN, 1988, p. 49). During this period, farmers were paid based on three systems: first, workers' performance was recorded with work points, and the net team income was distributed according to the work point after deducting for state taxes, the public welfare fund and so on during the year; second, only the number of days worked was recorded, and each worker's contribution was reevaluated based on the number of working days and his grade ranging from 6 to 10; third,

[3] The Republic of China was founded on 10 October 1911 as a result of the Wuchang Uprising, but it was not formally established until 1 January 1912. The Republic of China ended with the establishment of the People's Republic of China on 1 October 1949.

a "pacesetter" was chosen, and the others' performances were appraised with work points accordingly (LIN, 1988; NOLAN, 1988, p. 56-57).

No matter which system was employed, collective farming led to serious free-rider problems and high monitoring costs, thus agricultural productivity was not improved due to lacking incentives for laborers (LIN, 1988; NOLAN, 1988) and an institutional innovation was strongly demanded by farmers (LIN, 1992). In 1978, Xiaogang villagers in Fengyang County, Anhui Province, spontaneously initiated an innovation by secretly attempting to distribute their farmland, other resources and quotas to individual households. Farmers could obtain all extra agricultural products above set quotas, which provided great incentives to the farmers and brought a tremendous increase of yields a year later. Sensing the keen demand for institutional innovation, the central government first introduced the household responsibility system in poor agricultural areas, then nationwide; this system was *de facto* restricted in rich areas at its inception, but the restriction was not effective due to the great enthusiasm of farmers; it had spread to almost all rural areas in China by the end of 1983 (LIN, 1988).

LIN (1988) commented on the HRS as follows:

"It is worth emphasizing that the household responsibility system was worked out among farmers, initially without the knowledge and approval of the central government. It was generated through the efforts of peasants themselves and spread to the other areas because of its merits; it was not imposed by the central authority, unlike many other institutional changes that occurred in the last three decades. In short, the shift in the institution of Chinese agriculture was not carried out by any individual's will but evolved spontaneously in response to underlying economic forces."

Therefore, it was the farmer's choice to switch from a collective farm to a non-*collective individual farm, and the HRS rooted in the farmers' strong demand for institutional innovation in order to reduce transaction costs in terms of supervision in agricultural production and to promote productivity was a bottom-up institutio*nal change, as shown in the upper right portion of Figure 2-3. Given the prevalence of subsistence farming, farmers prefer diversified rather than specialized production (WU et al., 2005). In addition, land fragmentation is beneficial for crop diversification, which may help farmers avoid natural and economic risks to a certain degree when the topography of a village is diversified enough (HESTON and KUMAR, 1983; FENOALTEA, 1976). TAN et al. (2006) also found in their survey that farmers in suburban areas of the Jiangxi province of China preferred land fragmentation for its crop diversification, that is, they could plant more cash crops with the convenience of transportation (see "demand side" in Figure 2-3).

Land fragmentation may also lead to the structural change of production cost towards more labor input rather than capital input (TAN et al., 2008) (see "demand side" in Figure 2-3). In the absence of a labor market, land fragmentation indeed plays a role in absorbing rural surplus labor.

Evidence has shown that land fragmentation mainly came from voluntary de-collectivization to reduce supervision costs, and could help farmers diversify cropping structure and reduce capital input, implying the demand side driving forces (see "demand side" in Figure 2-3). A large number of studies have evaluated the achievement of HRS, for example FAN (1991) evaluated with a frontier production function that 63 % of productivity change came from HRS from 1965 to 1985. LIN (1992) estimated the contribution of rural reform to agricultural growth and found that institutional reform made up 48.69 % of output growth between 1978 and 1984. ROZELLE and SWINNEN (2004) also highlighted the success of agricultural reform of China in poverty reduction and productivity improvement compared with CEECs.

Nevertheless, land reform in China is not complete in terms of property rights, leading to the suppression of the land market and agricultural investment (CARTER and YAO, 2002; JACOBY et al., 2002), which increases the transaction costs of the land market. So current land fragmentation in China, even though it is driven by the demand side, suffers from property rights constraints, and farmers have little chance to adjust their plots through the land market (see "constraints" in Figure 2-3).

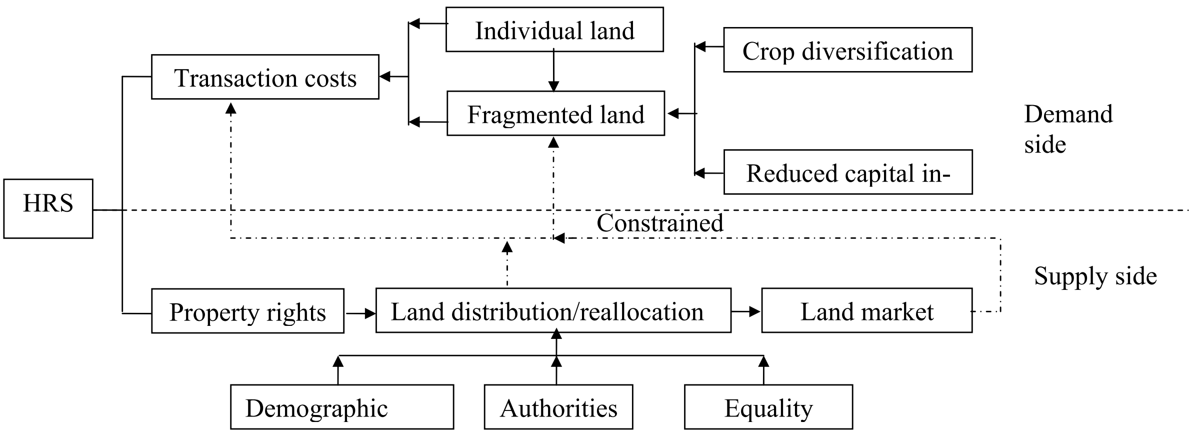
In light of the HRS, farmland is equally distributed to the farmers with respect to their household size, and farmers are granted quasi-private property rights (KUNG, 2002a). Other kinds of land that provide farmers more freedom to adjust their plots, such as contracted land, private plots and reclaimed land, also exist in some villages. However, such land covers only 10 % of the farmland in China (ROZELLE et al., 2005, p. 125). Land ownership is fragmented and any change of members in villages due to births or marriages affects the existing patterns of land entitlement; land reallocation is then inevitable, and land may be further fragmented (KUNG, 2000).

Land reallocations, which to a large extent depend on demographic changes, off-farm opportunities and local land resources, are also subject to the decision-making power exerted by a central or local government, or the village leaders (ROZELLE et al., 2005, p. 131), which sometimes may be arbitrary. Local leaders who conduct land redistribution have three purposes: a) protection of the leader’s personal interests; b) minimization of administrative costs; and c) improvement of both equity and land-use efficiency in remote areas characterized by subsistence agriculture and unequal access to off-farm labor activities (ROZELLE and LI, 1998). Even when land reallocations are carried out, they are rarely due to the systematic reduction of land fragmentation. As found by KUNG (2000), population change (42.7 %), requests by villagers (24.4 %), and orders by higher administrative bodies (24.4 %) were the three main reasons for land reallocation, while only 1.2 % of farmers wanted to reallocate land because of the scattering of plots.

Property rights constraints are imposed on both land use rights and land transfer rights. According to the survey of LIU et al. (1998), 63 % of all villages operate under constrained land use rights, meaning that the households are either restricted or sanctioned if they do not cultivate their farmland. Restrictions or sanctions are more serious in Zhejiang, where more farmers take off-farm work and over 90 % of villages impose sanctions when land is left uncultivated. Various restrictions are also embedded in land transfer rights, such as outright prohibition of land transfer and requirements that all transactions be either registered or approved by village authorities (LIU et al., 1998). In some rural areas, farmers can also reduce land fragmentation by exchanging plots nearby with plots far from home without going through land reallocation. This is the case if farmers are permitted to transfer their rights of use. However, participation in land markets is still rather low given the high transaction costs and the constrained land market on the supply side of the institution, which is only less than 3 % of their land rented, and renting mostly occurs among relatives, as reported by ROZELLE et al. (2005, p. 129).

In conclusion, land fragmentation in China stems from *quasi-demand* driving forces, and farmers voluntarily choose the de-collective farm but have little freedom to adjust plots due to incomplete property rights. In the absence of various input factor markets, the collective ownership of land is regarded as the second best choice in the non-commercialized agricultural economy (KUNG, 1995), and the collective decision in Chinese villages is a mixture of rational decision-making and political models (YAO, 2002). When the waste of labor is not serious and the opportunity costs of labor are not high, the costs of constraints resulting from incomplete property rights probably are not costly, but this is less likely the case when the rapid development of the labor market and land reallocation is incapable of achieving efficiency in terms of matching land and labor (BENJAMIN and BRANDT, 2002). The next section will analyze the consequences of land rental market development on land fragmentation.

Figure 2-3: The determinants of land fragmentation in China



Source: Author's presentation.

2.3 The effect of land rental market on land fragmentation

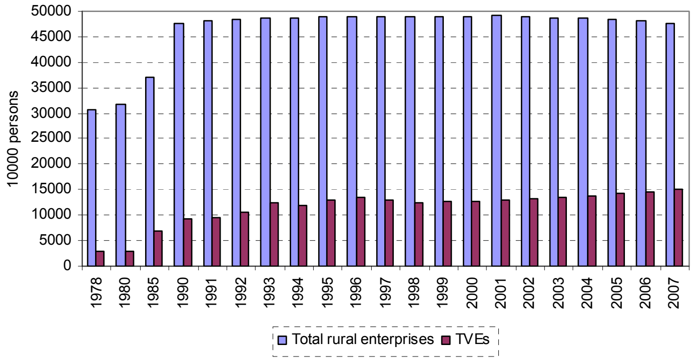
The presented analysis has revealed that HRS came from the demand of farmers, and when input factor markets were underdeveloped and farmers had little chance to participate in off-farm work, land distribution and reallocation were conducive to achieving a good match between land and labor (BRANDT et al., 2004). However, this land institution leads to a depression of the land market by granting incomplete property rights to farmers. Indeed, the depressed land market is regarded as one of the most prominent impediments to the development of the rural economy. This section focuses on analyzing the effect of the land market on land fragmentation, which is organized into the following three parts: the first two parts present the development of the labor and land markets, while the third part analyzes the effect of the land market on land fragmentation.

2.3.1 Development of the labor market

With the ongoing reforms and the opening up of the Chinese economy, collective, individual, private and foreign investment enterprises have increased, and thousands of Township and Village Enterprises (TVEs) have been established. These TVEs have provided many off-farm opportunities to rural laborers, and became the main source of employment in the 1980s, especially in coastal areas. As shown in Figure 2-4, the laborers employed by TVEs increased by 133 % from 1980 to 1985, and the number of rural laborers in TVEs was more than 90 million in 1990. Therefore, the TVEs contributed a great deal to the development of the labor market and poverty reduction in rural areas (ZHAO, 1997).

The ability to absorb rural labor surpluses leveled out, and the increased speed of TVEs slowed after 1990 (see Figure 2-4) due to redundancies caused by privatization or other forms of restructuring. However, rural laborers had more opportunities to take off-farm work in urban areas with the gradual relaxing of migration policy. DE BRAUW et al. (2002) reported that by 2000, 43 % of rural individuals participated in off-farm work. According to their estimation, there were 200 million rural individuals who took off-farm work in 2000, which has increased over the past decade. Many migrants left the villages seasonally, temporarily or permanently, which influences the land/labor ratio in rural areas, and thus pertains to the development of the land market.

Figure 2-4: Laborers employed by rural enterprises (1978-2007)



Source: NATIONAL STATISTICAL BUREAU (2008).

2.3.2 Land market development

To enhance the achievements of land market development after HRS, several land policies were created by the Chinese government. First, the land tenure limit was 15 years in 1984, and was later raised to 30 years in 1993. Permission to lease land was not technically granted until 1998. The Rural Land Contracting Law (RLCL) was implemented in 2003 and the land property rights of farmers were further strengthened in terms of tenure security, transferability and accountability (DEININGER et al., 2004).

Many empirical studies that have investigated the land rental market have invariably found that it was underdeveloped (BRANDT et al., 2004; CARTER and YAO, 2002; JACOBY et al., 2002; KUNG, 2002a; KUNG, 2002b; LIU et al., 1998). As revealed by the field study of ROZELLE et al. (2005, p. 129), the leasing of rural land appeared in China in 1988, and there was only 0.6 % land rented in. By 1995, despite more than 75 % of villages reporting land rental activity, the rented land was still less than 3 % (ROZELLE et al., 2005, p. 129; KUNG, 2002b). The 2003 RLCL technically prohibits land reallocation and is supposed to enhance the development of the land rental market. However, despite the introduction of the 2003 RLCL, land reallocation is still evidenced in rural China (DEININGER and JIN, 2009; TAO and XU, 2007).

By comparing the land transfer rights in Zhejiang, Jilin, Henan and Jiangxi, LIU et al. (1998) found that the areas with more land endowment or more off-farm opportunities had a better developed land market, while this was not true for the areas with less land or less off-farm opportunities. With the same dataset, CARTER and YAO (2002) distinguished the effects of land transfer rights into three regimes and argued that the less encumbered land property rights raised labor intensity for rent-out households, but not for rent-in households. The reason for this may be that the land is not only a property which farmers can profit from, but also functions as a social safety net when coverage of social security system for all farmers is impossible (DE LA RUPELLE et al., 2009; HUANG and PIEKE, 2003; CARTER and YAO, 2002).

2.3.3 The effect of land market on land fragmentation

Even though land transfer rights are constrained, land reallocation does not necessarily increase land fragmentation when the factor markets are poorly developed. As indicated by KUNG (1995), "It is indisputable that the equal land division rule has, indeed, given rise to scattering, there is no a priori reason for egalitarian tendencies to lead to increased fragmentation, an argument that seems implicit in the Chinese literature but whose empirical truth has not been established." Statistical data from the Ministry of Agriculture (1988) revealed that the average number of plots per household decreased from 10.7 to 9, and the average plot size increased from 9.2 mu to 10.7 mu from 1984 to 1988 (KUNG, 1995).

As agricultural income plays an important role for most farmers, it is more efficient to reduce land fragmentation by land reallocation, while the land rental market will obviously increase the degree of land fragmentation for the farmers who rent in land. This argument is strongly supported by the land tenure experiment in the Guizhou province (KUNG, 2002a), which indicates that even more property rights are granted to farmers who still prefer land reallocations or adjustment to the land rental market.

But with the development of the labor market, land reallocation may not achieve a good match of labor and land, while the land market must be developed to facilitate the appropriate movement of land and labor resources (BRANDT et al., 2004). For instance, farmers who are still working on-farm can rent in land from rural laborers, who take off-farm work or exchange remote plots to a closer one through the land rental market. In this manner, land fragmentation is reduced. As a result, the more developed the labor and land markets become, the less fragmented is the farm. However, if the labor is better developed, but the land market remains inactive, land reallocation may fail to adjust the land/labor ratio efficiently, and farmers will have little freedom to reduce the degree of land fragmentation.

Above all, the effect of the land market on the degree of land fragmentation depends on the development of the labor market. If the labor market is poorly developed and many rural laborers lack off-farm work opportunities, land reallocation is not necessary to increase land fragmentation for farmers; if the labor market is better developed, the development of the land market facilitates a reduction in the degree of land fragmentation.

2.4 Conclusions

To conclude, this chapter mainly investigates the causes of land fragmentation in China and finds that land fragmentation nowadays comes from the *quasi-demand* driving forces, which means that farmers voluntarily choose individual farm and land fragmentation, but are constrained by incomplete property rights. On one hand, land reallocation targeting egalitarianism is not necessary to increase land fragmentation when the labor market is underdeveloped. On the other hand, the land market helps to reduce the degree of land fragmentation as increasing rural laborers take off-farm work. For this reason, the effects of land fragmentation may be correlated with the development of the labor market; the implications of its development for land reform policies will be further discussed in chapter 8. In developing countries like China, where development of the labor market is always of great interest, we may wonder whether and how land fragmentation affects the off-farm labor supply; in the next section we will examine this issue.

3 THEORETICAL ANALYSIS OF THE EFFECTS OF LAND FRAGMENTATION

Our theoretical analysis is based on a microeconomic farm household model. A series of hypotheses and assumptions are discussed in order to gain insights into the impacts of land fragmentation on agricultural labor productivity and off-farm labor supply. This chapter is organized as follows: first, we theoretically analyze how land fragmentation affects the marginal productivity of labor. Second, we detect how land fragmentation influences off-farm labor supply in theory. Third, we demonstrate the plausibility of the theoretical model with different forms of functions. Lastly, we conclude.

3.1 Effects of land fragmentation in a microeconomic farm household model

We consider a separable farm household model with land fragmentation. The model follows the standard model as presented by BENJAMIN (1992), which is augmented by a land consolidation parameter α that determines how effectively labor can be used on the land.

We first outline the standard model. The farmer maximizes utility by choosing consumption c and leisure l, subject to a set of household characteristics, a, for example, its demographic composition. The household allocates family labor L to produce an aggregate agricultural output Y. The only other input is fixed land endowment A, so that $Y = Y(L; A)$, with $Y_1 > 0$ and $Y_{11} < 0$. The household may also supply labor off-farm, L^O, which yields an exogenously determined wage w. Total time endowment is $T(a)$. To simplify the exposition, we ignore the possibility that labor may also be hired. Hence, the farmer's problem is as follows:

$\max u(c, l; a)$ w.r.t. c, l, L^O, L s.t. (3-1)

$c = Y(L; A) + wL^O$, (3-2)

$l + L + L^O = T$. (3-3)

In this model with an exogenous wage, profits are maximized independent of the household's utility function. The optimal amount of labor supplied on the farm depends only on the production technology and the wage, following the optimality condition $Y_1 = w$. Given the leisure choices of the household l, which depend on a, off-farm labor supply $L^O \geq 0$ is determined as a residual. This is shown in Figure 3-1 (a).

We now introduce an exogenous land consolidation parameter $\alpha \in]0,1]$, which measures the efficiency of labor use on the plot. If α is close to 1, almost all the time allocated to farming is actually spent on the plot. If α is closer to 0, much time is used for travelling to and from the plot, or for other unproductive activities that result from land fragmentation, such as cumbersome water management or less efficient machinery use (WAN and CHENG, 2001). Hence, the amount of labor productively used is reduced. We write $Y = Y(\alpha L; A)$ in the presence of land fragmentation, where αL is the level of effective on-plot labor. As an illustration, consider that L is measured in days spent on-farm, each day covering 10 working hours. If $\alpha = 0.8$, the household spends 2 hours per day for travelling and other non-productive activities, and 8 hours effectively on the plot. If the household chooses to spend many days on-farm, the absolute time spent non-productively will also increase proportionally.

We are interested in the effects of varying α on labor use in the household. If land fragmentation is modeled in the abovementioned way, the first point to note is that more fragmented land unambiguously reduces output. To see this, consider the effect of fragmentation on output as follows:

$$\frac{\partial Y}{\partial \alpha} = \frac{\partial Y}{\partial \alpha L} L . \qquad (3\text{-}4)$$

With $Y_1 > 0$, this effect is unambiguously positive, which implies a negative impact of fragmentation on the absolute level of output.

Secondly, note that the effect of land fragmentation on the marginal product of on-farm labor is undetermined. The marginal productivity of labor (MPL) in the model with land fragmentation is given as follows:

$$\frac{\partial Y}{\partial L} = \alpha \frac{\partial Y}{\partial \alpha L} . \qquad (3\text{-}5)$$

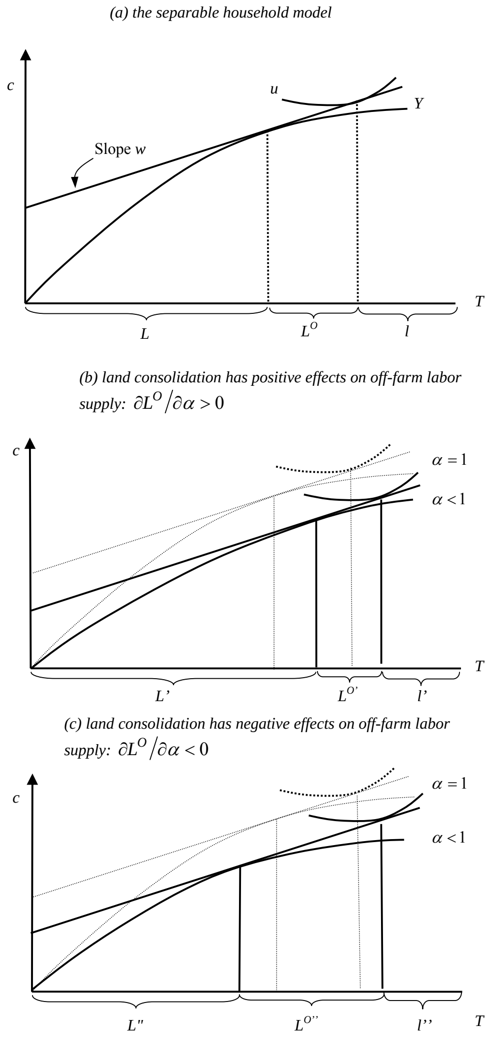
The effect of α on the MPL is then:

$$\frac{\partial^2 Y}{\partial L \partial \alpha} = \frac{\partial Y}{\partial \alpha L} + \alpha L \times \frac{\partial^2 Y}{\partial (\alpha L)^2} . \qquad (3\text{-}6)$$

The first term on the right-hand side denotes the marginal product of effective on-plot labor on output, which is positive given our assumptions on technology and profit maximization. The second term is the effective labor on-plot input, which is non-negative according to our assumption. The third term is the second derivative of the production function with regard to effective labor input, which is negative given our concavity assumption $Y_{11} < 0$. Hence, a negative number is added to a positive one, so that the sign of the composite is theoretically undetermined.

A simulation exercise will be shown in section 3.3, and commonly used functional forms in applied production analysis will exhibit possibilities of both positive and negative effects. For example, a typical quadratic production function will exhibit a range where both a positive and a negative effect of consolidation on labor productivity can be found (see the demonstration in section 3.3). In Figure 3-1, we show functional forms that imply both a negative (chart (b)) and a positive effect (chart (c)) of land consolidation on the MPL.

Figure 3-1: Land fragmentation in the separable agricultural household model



Source: Author's depiction.

3.2 The effects of land fragmentation on off-farm labor supply

3.2.1 Theoretical framework

This sub-section sheds light on the consequences of land fragmentation on off-farm labor supply. In line with the standard microeconomic farm household model presented in the last section, the optimum time allocation choice of a household is made by maximizing the utility function. Plugging the consumption and total time endowment constraints into the farm household utility function engenders the Lagrangean function:

$$u(c,l;a)+\lambda(Y(L;A)+w^O L^O-c)+\mu(T-l-L-L^O)\,. \qquad (3\text{-}7)$$

The first-order conditions of this Lagrangean function with respect to L and L^O are generated to optimize household choices:

$$\lambda\frac{\partial Y}{\partial L}-\mu=0\,, \qquad (3\text{-}8)$$

$$\lambda\frac{\partial Y}{\partial L^O}-\mu=0\,, \qquad (3\text{-}9)$$

$$\frac{\partial u}{\partial l}-\mu=0\,, \qquad (3\text{-}10)$$

$$\frac{\partial u}{\partial c}-\lambda=0\,. \qquad (3\text{-}11)$$

Substituting equation (3-10) into equation (3-11), the price of leisure time is:

$$\frac{\partial c}{\partial l}=\frac{\mu}{\lambda}\,. \qquad (3\text{-}12)$$

In the separable labor market, both on-farm and off-farm wage are exogenous and not influenced by household characteristics and preferences (BENJAMIN, 1992; SKOUFIAS, 1994; SADOULET and DE JANVRY, 1995, p. 140-158), so

$$\frac{\partial Y}{\partial L}=w^f=\frac{\partial Y}{\partial L^O}=w=\frac{\partial c}{\partial l}=\frac{\partial Y}{\partial l}=w^l=\frac{\mu}{\lambda}\,. \qquad (3\text{-}13)$$

The level of L^O is given by $L^O=T-l-L$, so that:

$$\frac{\partial L^O}{\partial \alpha}=-\frac{\partial l}{\partial \alpha}-\frac{\partial L}{\partial \alpha}\,. \qquad (3\text{-}14)$$

The effects of land fragmentation on off-farm labor supply depend on the effects of land fragmentation on leisure time and on-farm time, since the household is subject to a total time endowment constraint. When the effect of α on the MPL is undetermined, we do not know a priori whether the household will employ more or less labor on-farm as a result of varying land fragmentation. *The effect of land fragmentation on off-farm labor supply is hence also undetermined.*

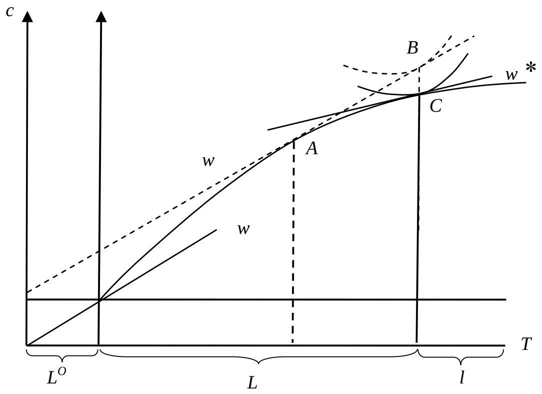
Following equation (3-12), the plausible hypothesis will be that $\frac{\partial l}{\partial \alpha} > 0$, implying that richer households consume more leisure (as depicted in Figure 3-1 (b) and (c)).When land consolidation decreases on-farm employment, and an increase of leisure time does not exceed the decrease of agricultural work, land consolidation will promote the off-farm labor supply (Figure 3-1 (b)). Conversely, when land consolidation results in an increase of on-farm employment without hiring laborers, the off-farm labor supply will thus be reduced, as depicted in Figure 3-1 (c).

Numerous authors have pointed out that the assumption of a perfect labor market is a strong one in many empirical settings, including China (BENJAMIN, 1992; BOWLUS and SICULAR, 2003; WANG et al., 2007). For example, there may be an exogenously imposed upper bound to the number of hours a household can find employment at the going market rate, and this bound may be lower than actual labor supply. There are several plausible reasons for such constraints in the Chinese context. In addition to a simple lack of jobs in rural areas, rural inhabitants may not possess the necessary education for off-farm employment (YANG, 2004), the allocation of jobs by village leaders may be based on non-market, political and social criteria such as family connections or household income (BOWLUS and SICULAR, 2003), or farm households working off-farm may fear the loss of their rights to land use (KUNG, 2002; WANG et al., 2011). In such cases of off-farm labor rationing, the separability property of the model breaks down.

Following BENJAMIN (1992), the labor allocation for agricultural households is depicted in Figure 3-2. When there are constraints on labor supply side, the agricultural households can only supply a fixed amount of off-farm labor, for example L^{O}. The optimal on-farm labor input is no longer at point A but point C in Figure 3-2, and the on-farm wage is the shadow wage, which is lower than off-farm wage. In this case, the land consolidation does not affect off-farm labor supply anyway. If in the extreme there is no off-farm employment opportunity at all, land consolidation will fail to affect observed off-farm employment. It is rather likely to increase the amount of leisure time and/or somewhat reduce hidden unemployment, depending on the household's preferences for leisure (or home time) consumption (BROOKS and TAO, 2003; HO et al., 2004).

In this monograph, we will not discuss the source of nonseparability; the imperfect labor market explicitly implies that farmers have the chance to access off-farm work, but the amount of time is rationed (YAO, 1999). When time rationing captures the labor market, farmers lack off-farm work opportunities or lack human capital to access off-farm work, so land consolidation will have no impact on off-farm labor supply. In this case, land consolidation may fail to affect the off-farm labor supply and only increase the amount of leisure time in the first scenario (land consolidation decreases MPL). And in the second scenario (land consolidation increases MPL), land consolidation may help farmers to release hidden unemployment (BROOKS and TAO, 2003; HO et al., 2004, p. 1) but fail to affect off-farm labor supply.

Figure 3-2: Off-farm labor supply in a non-separable agricultural household model



Source: Adapted from BENJAMIN (1992).

3.2.2 Specification of the off-farm labor supply function

We assume that off-farm labor participation is determined by the anticipated off-farm wage, human capital and other local labor market characteristics. The off-farm labor supply function in the labor market is as follows:

$$L^O = L^O(w, D, \alpha; A) . \qquad (3\text{-}15)$$

In the presence of imperfection in the labor market, specialization farmers may intend to participate in off-farm work to diversify income risk (BUCHENRIEDER, 2005) resulting in a positive correlation between on-farm and off-farm wage. Therefore, the off-farm wage is endogenous and an instrumental strategy should be adopted (SKOUFIAS, 1994; SUMNER, 1982). In China, the off-farm wage has been found to be associated with government interventions (YAO, 1999), which likely leads to a correlation between off-farm wage and error terms. Normally the Fixed Effects-Two Stage Least Square (FE-2SLS) model can obtain robust results in the presence of unobserved heterogeneity and endogeneity, as we will discuss in section 4.1 and 4.2 (p. 37-38). However, this model fails to capture households which do not provide off-farm labor in a specific year since off-farm wage is only observable with participation in off-farm work. Therefore, the estimation of equation (3-15) is not consistent when the residuals are correlated with sample selections and methodological issues of sequential estimations in terms of endogeneity and selection bias arise (SUMNER, 1982; WOOLDRIDGE, 2002, p. 551-552). In chapter 7, we will address these issues and obtain consistent results concerning the off-farm labor supply function with panel data by controlling the time-invariant heterogeneity, endogeneity, sample selection bias and clustering of observations at the same time.

3.3 A simulation test of the theoretical model

This section will employ a numerical methodology to show the existence of different effects of land fragmentation on MPL, which includes four parts. First, the hypotheses are derived in light of the theoretical framework in section 3.1, and several production forms are specified. Second, simulated input data is generated to calculate the output on both consolidated and fragmented farms with respect to exemplified forms of the production function. Third, the simulation outcome is presented for comparison with our theoretical model. Lastly, we draw conclusions.

3.3.1 Hypotheses and specifications

The theoretical model in section 3.1 reveals that the effect of land consolidation on the MPL is determined by the total magnitude of the land fragmentation costs and benefits entered into the production function, which could be positive, negative or neutral as illustrated in Table 3-1. When the second derivative of the production function is larger than $-\frac{\partial Y}{L\partial L}$, the effect of land consolidation on MPL is positive. The effect is negative when the second derivative of the production function is smaller than $-\frac{\partial Y}{L\partial L}$. Otherwise, land consolidation has a neutral impact on MPL.

Table 3-1: The effect of land consolidation on MPL

Positive impact on MPL	*Neutral impact on MPL*	*Negative impact on MPL*
$\frac{\partial MPL}{\partial \alpha} > 0$	$\frac{\partial MPL}{\partial \alpha} = 0$	$\frac{\partial MPL}{\partial \alpha} < 0$
$\frac{\partial^2 Y}{\partial(\alpha L)^2} > -\frac{\partial Y}{L\partial L}$	$\frac{\partial^2 Y}{\partial(\alpha L)^2} = -\frac{\partial Y}{L\partial L}$	$\frac{\partial^2 Y}{\partial(\alpha L)^2} < -\frac{\partial Y}{L\partial L}$

Thus, the effect of land consolidation on MPL is determined by the shape of the production function with respect to land fragmentation, given unchanged technology that can be simulated by defining different types of production functions. Here, we illustrate specific forms of exponential (equation (3-16)), quadratic (equation (3-17)) and semi-log (equation (3-18)) production functions, respectively, and simulate production with a certain amount of labor input under the assumption that fragmented land abates 25 % of the total labor input compared with consolidated land ($\alpha = 0.75$), while other inputs are the same as shown in equation (3-19).

The functional forms are:

Exponential production function: $Y = 170 - 160e^{-L/30}$. (3-16)

Quadratic production function: $Y = 20 + 2.8L - 0.016L^2$. (3-17)

Semi-log production function: $Y = 45\ln(0.4L)$. (3-18)

Effective labor input on fragmented land: $L_f = 0.75L_c$. (3-19)

3.3.2 Numerical simulation results

The yields on both consolidated and fragmented land are calculated with effective labor input according to the above equations as shown in Table 3-2. The first two columns are effective labor input on consolidated and fragmented farms separately, and the effective labor input on fragmented farms is always 75 % of that on consolidated farms since we assume that the relationship between effective labor input and total labor input is always linear and constant.

Table 3-2: Numerical simulation results

Labor input on consolidated land (days)	*Labor input on fragmented land (days)*	*Exponential production function*		*Quadratic production function*		*Semi-log production function*	
		Y exp consol.	*Y exp frag.*	*Y exp consol.*	*Y exp frag.*	*Y exp consol.*	*Y exp frag.*
10	7.5	55	45	46.4	40.1	62	49
20	15	88	73	69.6	58.4	94	81
30	22.5	111	94	89.6	74.9	112	99
40	30	128	111	106.4	89.6	125	112
50	37.5	140	124	120	102.5	135	122
60	45	148	134	130.4	113.6	143	130
70	52.5	154	142	137.6	122.9	150	137
80	60	159	148	141.6	130.4	156	143
90	67.5	162	153	142.4	136.1	161	148
100	75	164	157	140	140	166	153

Source: Author's simulation and calculation.

3.3.3 Simulation of the theoretical model

The simulated graphs are depicted in Figure 3-3, Figure 3-4 and Figure 3-5, with the vertical line in the first two figures denoting the neutral point where the second derivative of production function equals $-\frac{\partial Y}{L\partial L}$. Keeping all other inputs constant, the second derivative of the production function is larger than $-\frac{\partial Y}{L\partial L}$ in zone 1 of the first two figures (Figure 3-3 and Figure 3-4), indicating a positive impact of land consolidation on MPL, while the second derivative of the production function is smaller than $-\frac{\partial Y}{L\partial L}$ in zone 2, indicating a negative impact of land consolidation on MPL. The MPL on the fragmented and consolidated farms are parallel in the case of the semi-log production function as shown in Figure 3-5.

Figure 3-3: Simulation of the exponential production function

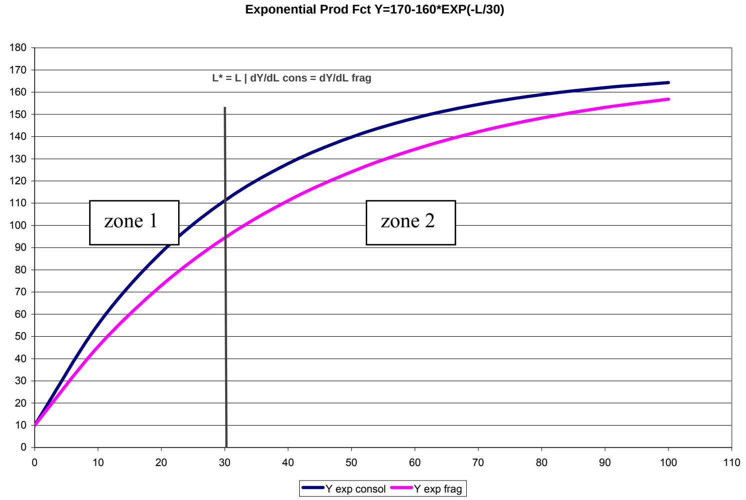


Figure 3-4: Simulation of the quadratic production function

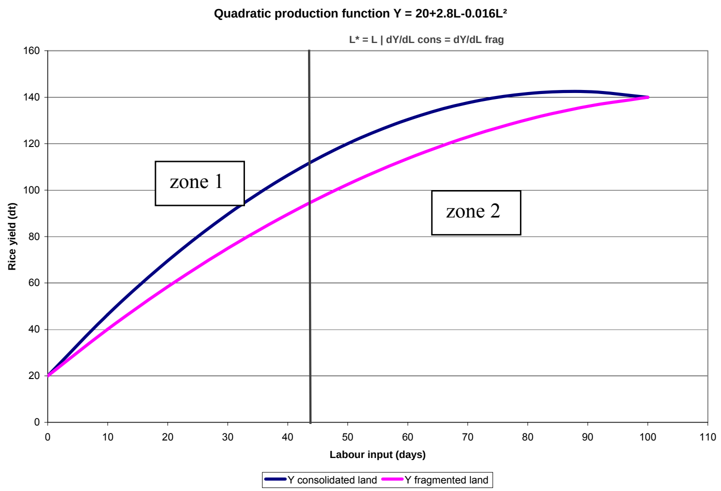
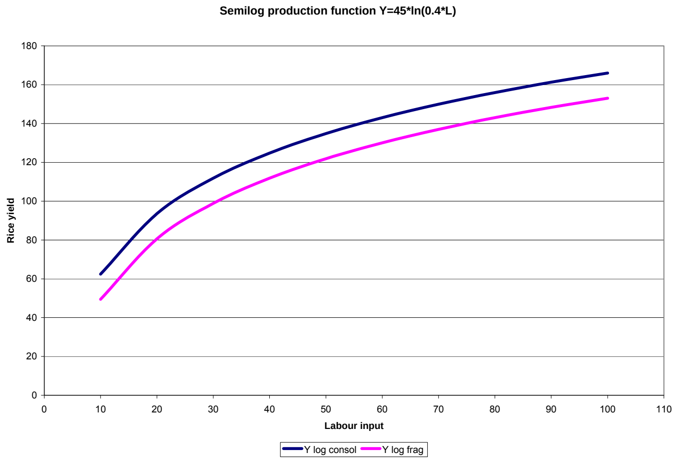


Figure 3-5: Simulation of the semi-log production function



Calculating the first and second derivatives with respect to the labor input for the exponential and quadratic production function yields a set of differences that are listed in Table 3-3. When labor input is less than 30 days for the exponential production function, land consolidation has a positive impact on MPL; it approaches the neutral point when the labor input is at 30 days. Afterwards, with the increase of labor input, the second derivative of the exponential production function exceeds the first derivative. Thus, land consolidation has a negative impact on MPL. The effect of land consolidation on MPL for the quadratic production function also experienced a similar evolution process, with the neutral point being 43.5 days.

Table 3-3: Evolution process of the effect of land consolidation

Labor input on consolidated land (days)	*Labor input on fragmented land (days)*	*Exponential production function*			*Quadratic production function*		
		$\partial Y/\partial L$	$\partial^2 Y/\partial L^2$	$\partial^2 Y/\partial L^2 - \partial Y/\partial L$	$\partial Y/\partial L$	$\partial^2 Y/\partial L^2$	$\partial^2 Y/\partial L^2 - \partial Y/\partial L$
10	7.5	0.382	0.127	0.255	0.248	0.032	0.216
20	15	0.137	0.091	0.046	0.108	0.032	0.076
30	22.5	0.065	0.065	0.000	0.061	0.032	0.029
40	30	0.035	0.047	-0.012	0.038	0.032	0.006
50	37.5	0.02	0.034	-0.013	0.024	0.032	-0.008
60	45	0.012	0.024	-0.012	0.015	0.032	-0.017
70	52.5	0.007	0.017	-0.01	0.008	0.032	-0.024
80	60	0.005	0.012	-0.008	0.003	0.032	-0.029
90	67.5	0.003	0.009	-0.006	-0.001	0.032	-0.033
100	75	0.002	0.006	-0.004	-0.004	0.032	-0.036

Source: Author's own calculation.

To sum up, this section provides evidence for the theoretical model with a simulation approach. The effect of land consolidation on MPL is determined by the total magnitude of land fragmentation costs and benefits entering into the production function, which is not known *a priori*. For example, a typical quadratic production function will exhibit a range where both a positive and a negative effect of consolidation on labor productivity can be found. To the contrary, the CD function allows only a positive effect due to the rigid labor elasticity. Therefore, in order to detect the effect of land fragmentation, a flexible production function is required in empirical studies.

3.4 Conclusions

This chapter provides a theoretical analysis on how land fragmentation affects MPL and off-farm labor supply, and argues that the effect of land fragmentation on MPL depends on the local shape of production function and is not known *a priori*. Further, the simulation test based on the theoretical model confirms the argument. The effect of land fragmentation on off-farm labor supply is determined by both the effect of land consolidation on agricultural labor supply and that on leisure time. Since the effect of land fragmentation on agricultural labor supply is undetermined, the effect of land fragmentation on off-farm labor supply is therefore. Our empirical studies in chapter 6 and chapter 7 will empirically estimate the effects of land fragmentation and solve the problems presented above.

4 METHODOLOGICAL CHALLENGES

To measure the effects of land fragmentation, the empirical study is separated into two steps with respect to two main models. The first step is to estimate the effect of land fragmentation on agricultural labor productivity by employing a flexible production function. An off-farm labor supply function is then adopted to estimate the impacts of land fragmentation on off-farm labor supply in the second step. In the empirical estimation, several econometrical methodological challenges such as unobserved heterogeneity, endogeneity, clustering of observations and too many covariates are confronted by both models. This chapter focuses on searching for solutions to these problems. In addition, the strategies to read off elasticities easily from the estimated results and to demean the production function are also elaborated.

4.1 Unobserved heterogeneity – Panel data strategies

One of the most important problems here is to tackle the unobserved heterogeneity in the estimation. For example, in a production function (see equation (6-1) in chapter 6, p. 66), individual farm output may be affected by unobserved characteristics of the farm. These characteristics may be due to "management bias" as introduced to the literature by MUNDLAK (1961), or may reflect socio-demographic or geographic characteristics of the farm that are constant over time. For example, soil fertility, management ability of farmers and technology are supposed to be correlated with inputs. Since the panel data is available in our case, the typical way to eliminate the influence of these factors is to use a fixed-effects or "within groups" estimator (GREENE, 2008, p. 191).

The unobserved effects model can be written as follows (WOOLDRIDGE, 2002, p. 251):

$$y_{it} = \beta x_{it} + v_i + u_{it}, \quad t = 1,......,T, \; i = 1,......,n, \qquad (4\text{-}1)$$

where x_{it} is $1 \times K$ vectors containing all the observable variables, v_i is the unobserved heterogeneity controlling for unobserved effects, and u_{it} represents the idiosyncratic disturbances. It is critical to focus on whether v_i should be treated as a random effects (RE) model or a fixed effects (FE) model in the estimation. The RE means the unobserved effect is independent of explanatory variables and it changes over time, while the fixed effect indicating the unobserved effect is correlated with explanatory variables and is constant over time. However, we do not know if the FE model or the RE model applies in the estimation. In our estimation, unobserved heterogeneity is expected to be correlated with inputs in agricultural production, suggesting an FE model, while a Hausman specification test developed by HAUSMAN (1978) serves as an approach to detect whether the difference in coefficients is systematic or not. The null hypothesis is that the difference in coefficient is not systematic, implying the RE, while a rejection of the null hypothesis implies the FE.

4.2 Endogeneity – Instrumental variable method

A central concern in a function estimation is endogeneity. While variations in dependent variables may well be explained by variations in explanatory variables on statistical grounds, the concern is that this correlation may be spurious and not due to an appropriately specified causal effect. Hence, the "independent" part of the i.i.d.-assumption is violated. To the extent that the omitted factors are constant and their effect is additively separable, an FE approach yields unbiased estimates of the causal effect. However, if a variation of the dependent variable over time is endogenous, which is likely to be the case for at least some explanatory variables, the FE model will fail to obtain an unbiased estimation.

In our estimation, the endogeneity problem may violate the consistent estimate of the off-farm labor supply function due to the adoption of observed off-farm wage. As has been claimed in section 3.2 (p. 28), the off-farm wage is probably not independent of error terms due to a household specific reason and government interventions (YAO, 1999; SUMNER, 1982), which gives rise to the problem of endogeneity. If the off-farm wage is positively (negatively) correlated with the on-farm wage due to unobserved disturbance shifting, then the effect of the off-farm wage will be underestimated (overestimated) (SUMNER, 1982). A better approach for estimating the off-farm supply function is not to use the observed off-farm wage directly, but to instrument it with Instrumental Variables (IVs).

Such IVs must not be part of the estimated function, but should have explanatory power with regard to the endogenous variable(s) and should be uncorrelated with the idiosyncratic disturbance. One commonly applied strategy to use IVs is the 2SLS.

In line with WOOLDRIDGE (2002, p. 83), we write the equation

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_K x_K + u\,, \qquad (4\text{-}2)$$

where $\beta_0 ...... \beta_K$ are the estimated coefficients and u is the idiosyncratic disturbance. If x_K is the endogenous variable, which means

$$E(u) = 0\,, \qquad Cov(x_j, u) = 0\,, \qquad j = 1,2,......, K-1 \qquad (4\text{-}3)$$

but $Cov(x_K, u) \neq 0$. (4-4)

The IV approach is motivated to solve the endogeneity of x_K by introducing the exogenous variable z, which satisfies

$Cov(z,u) = 0$ and $Cov(z, x_K) \neq 0$. (4-5)

The basic idea of the 2SLS approach is to regress x_K on all exogenous variables on the first-stage regression:

$$x_k = \varpi_0 + \varpi_1 x_1 + \varpi_2 x_2 + ... + \varpi_{K-1} x_{K-1} + \gamma_1 z + \varepsilon_K , \quad (4\text{-}6)$$

where the idiosyncratic disturbance term ε_K is uncorrelated with $x_1, x_2 ......, x_{K-1}$, and z by definition. The coefficients $\varpi_0 ,......\varpi_{K-1}$, and γ_1 are the estimated coefficients, but $\gamma_1 \neq 0$. The instrumental variables are sometimes distinguished as being internal instruments and external instruments. Here, $x_1, x_2 ......, x_{K-1}$ are the internal instruments and z indicates the external instrument(s).

Then we treat $\hat{x}_K$ (the prediction of x_K) as the regressor to replace x_K and estimate the following linear equation on the second-stage regression:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_{K-1} x_{K-1} + \beta_K \hat{x}_K + u \quad (4\text{-}7)$$

If there is only one endogenous variable and one external instrument, we cannot test the validity of the instrument. Whereas, as long as the number of correlated external instrumental variables is more than the number of endogenous variables, the Sargan-Hansen test serves as an approach to identify the quality of instruments by testing the over-identifying restrictions (BAUM et al., 2007). Assume that the total exogenous variables are $1 \times L$ vector and the internal instrumental variables are $1 \times L_1$ vector, then the external instrumental variables are $1 \times L_2$ and $L_2 = L - L_1$. For the 2SLS estimator, the test for the over-identification restriction is obtained as NR_u^2 from the regression of the IV residuals on the full set of instruments. The joint null hypothesis is that the instruments are valid, while a rejection of the null hypothesis indicates that the instruments' validity should be reconsidered.

In the production function, the land and number of plots are assumed to be exogenous and thus serve as their own instruments due to the restrictions of the Chinese land market as described in section 2.2 (p. 11). Capital input is regarded as exogenous in our estimation for both simplification and concentration. Labor input is the most likely to be an endogenous variable, so we instrument labor input and all interaction terms where these inputs are involved with a set of exogenous variables in the production function. However, no satisfied set of IVs has been found. In the off-farm labor supply function, the off-farm wage is endogenous due to the abovementioned reasons, and all the other variables are assumed to be exogenous. Hence an IV method will be implemented in chapter 7.

4.3 Clustering of observations – Cluster robust samples

Recently, econometricians have paid increasing attention to the effects that a specific survey design may have on the reliability of estimates, in particular on the robustness of standard errors. A common problem is that observations come from clustered samples, for example many households from the same village may share similar concerns, while they are not similar to those of a different village. This is also the case in our current sample. DEATON (1997, p. 73-78) argued that standard errors were too small if the conventional formula was applied, because the "identical" part of the i.i.d.-assumption was violated. To see how, for example, the regression equation for household s in cluster i is:

$$y_{is} = \beta x_{is} + c_i + u_{is} = \beta x_{is} + \sigma_{is} . \qquad (4\text{-}8)$$

The regression error term σ_{is} is composed of the sum of a cluster component c_i and an individual component u_{is}. Both components have a mean of 0, and their covariance structure can be derived from the assumption that the c's are uncorrelated across clusters, and the u's both within and across clusters. Hence,

$$\begin{aligned} &E(\sigma_{is}^2) = \delta^2 = \delta_c^2 + \delta_u^2 \\ &E(\sigma_{is}\sigma_{it}) = \delta_c^2 = \rho\delta^2, s \neq t \qquad (4\text{-}9) \\ &E(\sigma_{is}\sigma_{i's}) = 0, i \neq i'. \end{aligned}$$

Some correction for this heteroscedasticity based on the cluster-specific regression residuals is suggested, following WHITE (1984). Assuming that the number of clusters is n, the cluster robust standard error can be calculated as:

$$\tilde{V}(\hat{\beta}) = (X'X)^{-1}(\sum_{i=1}^{n} X'_i e_i e'_i X_i)(X'X)^{-1} . \qquad (4\text{-}10)$$

$\tilde{V}$ is a block-diagonal matrix with one block for each cluster, e_i is the OLS residuals from each cluster, X is $s \times k$ matrix, while k is the number of independent variables.

4.4 Too many covariates – Partialing out method

When the clustering of observations is controlled, it is more likely that the covariance matrix Γ of orthogonality conditions is not of full rank and the over-identification test is infeasible since the optimal weighting matrix $W = \Gamma^{-1}$ cannot be obtained. The partialling out method just addresses this problem, and partials out some or all exogenous variables for matrix Γ.

The partialling out method is used to express the coefficient of one covariate through the dependent variable and the residuals from the projection of this covariate on all the other covariates, which means that the consistent estimation of some covariates can be obtained without using all exogenous covariates directly. Therefore, the method provides an efficient approach to conserve on the degrees of freedom. As suggested by WOOLDRIDGE (2006, p. 84), we suppose that there are K independent variables,

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + ... + \hat{\beta}_K x_K . \qquad (4\text{-}11)$$

If we want to partial out all the other exogenous covariates in the regression $x_2 ...... x_K$, the expression of $\hat{\beta}_1$ is:

$$\hat{\beta}_1 = (\sum_{i=1}^{n} \hat{r}_{i1} y_i)/(\sum_{i=1}^{n} \hat{r}_{i1}^2), \qquad (4\text{-}12)$$

where the $\hat{r}_{i1}$ are the OLS residuals from a simple regression of x_1 on $x_2 ...... x_K$ with the available sample. The equation (4-12) shows that the coefficient of x_1 can be obtained by a projection of y on $\hat{r}_{i1}$, thus $\hat{\beta}_1$ measures the effect of x_1 on y after $x_2 ...... x_K$ have been partialled out or netted out. It is also possible to partial out not all of the other exogenous covariates but some of them, for example, x_2 and x_3. Then, the $\hat{r}_{i1}$ are the OLS residuals from a simple regression of x_1 on x_2 and x_3 with the available sample, and still the consistent coefficient of x_1 can be estimated by a projection of y on $\hat{r}_{i1}$. In chapters 6 and 7, we will use the partialling out method in order to obtain clusters of robust standard errors.

4.5 Reading off elasticities easily – Demeaning of samples

For a translog production function, it is very inconvenient to read off elasticities from the estimation results. One way to solve this problem is to demean the samples with the geometric sample means before the estimation. Assume that a translog production function is:

$$\ln y = \beta_0 + \sum_{j=1}^{K} \beta_j \ln x_j + 0.5 \sum_{i=1}^{K} \sum_{j=1}^{K} \beta_{ij} \ln x_i \ln x_j \,. \qquad (4\text{-}13)$$

Following tradition, the elasticities of inputs are calculated at geometric sample means, the elasticity of input x_1 of all inputs is

$$\beta_1 + \sum_{i=1}^{K} \beta_{i1} \ln \bar{x}_i \ln \bar{x}_1 \,, \qquad (4\text{-}14)$$

……

The elasticity of input x_K of all inputs is

$$\beta_K + \sum_{i=1}^{K} \beta_{iK} \ln \bar{x}_i \ln \bar{x}_K \,. \qquad (4\text{-}15)$$

$\bar{x}_1 ...... \bar{x}_K$ are the corresponding geometric sample means of $x_1 ...... x_K$. So

$$\begin{aligned} \bar{x}_1 &= \sqrt[N]{x_{11} x_{12} ...... x_{1N}} \\ &...... \\ \bar{x}_K &= \sqrt[N]{x_{K1} x_{K2} ...... x_{KN}} \end{aligned} \qquad . \qquad (4\text{-}16)$$

Plugging equation (4-16) into equation (4-14) and equation (4-15), the elasticity of x_1 becomes

$$\beta_1 + \frac{\sum_{i=1}^{K} \beta_{i1} \overline{\ln x_i}\,\overline{\ln x_1}}{N^2}, \qquad (4\text{-}17)$$

……

and the elasticity of x_K becomes

$$\beta_K + \frac{\sum_{i=1}^{K} \beta_{iK} \overline{\ln x_i}\,\overline{\ln x_K}}{N^2}. \qquad (4\text{-}18)$$

The above equations indicate that if all the $\overline{\ln x_i}$ are zeros, the elasticity of input x_i is just β_i, thus the elasticities of inputs can be easily read off. To achieve this goal, all the inputs and outputs should be demeaned according to the geometric sample means, then equation (4-13) is transformed into the following equation:

$$\ln y - \overline{\ln y} = \beta_0 + \sum_{j=1}^{K} \beta_j (\ln x_j - \overline{\ln x_j}) + 0.5 \sum_{i=1}^{K} \sum_{j=1}^{K} \beta_{ij} (\ln x_i - \overline{\ln x_i})(\ln x_j - \overline{\ln x_j}). \quad (4\text{-}19)$$

For this reason, all the observations used in the translog function in chapter 6 are demeaned in terms of the formula above (equation (4-19)).

4.6 Conclusions

This chapter introduces the main empirical methodologies that will be employed in the next two chapters. To deal with the unobserved heterogeneity due to the panel data, an FE or RE model is required, and the Hausman test is used to decide which model is the appropriate one. The 2SLS is supposed to solve the endogeneity of inputs by instruments which are correlated with endogenous variables but independent of the idiosyncratic disturbance. When the clustering characteristic captures the observations, a cluster-robust correction of standard error should be introduced. To accomplish the cluster-robust correction, it is necessary to partial out some of the exogenous covariates to conserve on the degrees of freedom without pertaining to the consistent estimation of the concerned coefficients. Lastly, a demeaning of production function in terms of geometric sample means is conducted to easily elasticities from the estimated results.

5 DESCRIPTION OF RESEARCH REGIONS AND DATA ISSUES

Before we present the empirical studies, this chapter provides a general introduction of research regions and a clarification of how to clean the data. In the following, we begin with the development of agriculture in Zhejiang, Hubei and Yunnan. The second part introduces the degree of farm size and land fragmentation in the research regions. The sequent part provides an overview of rural development such as rural employment structures and rural income structures. Subsequently, the chapter presents the data cleaning strategy applied in the empirical study before moving on to the conclusions.

5.1 Agriculture

Our research selects three typical provinces from the east and west of China, Zhejiang, Hubei and Yunnan, where the Gross Domestic Product (GDP) structure, agricultural environment, agricultural productivity, and production technology are very diversified.

5.1.1 Zhejiang

Zhejiang lies in the southeast of China, which consists mostly of hills that account for approximately 70 % of its total area. Zhejiang's coastline is 6,400 km long, which is the longest in China. The main soil type is yellow soil and red loam. There are four distinct seasons in this province, the average temperature is 15-18 degrees Celsius, the average yearly rainfall is 980~2000mm, and the average yearly sunlight is 1710~2100 hours (WIKIPEDIA, 28 Oct. 2010).

Zhejiang is one of the country's most developed provinces; its GDP ranked fourth of provinces in China in 2008. The agricultural sector in Zhejiang province accounted for 11.8 % of total GDP in 1999, though this number is decreasing; it is accompanied by the rapid development of the tertiary sector, and the primary sector accounted for only 5.1 % of its total GDP in 2008, as shown in Table 5-1.

Table 5-1: Structure of GDP in Zhejiang province (1999-2008)

Year	*Primary sector (%)*	*Secondary sector (industry) (%)*	*Tertiary sector (services) (%)*
1999	11.8	54.1	34.1
2000	11.0	52.7	36.3
2001	10.3	51.3	38.4
2002	8.9	51.1	40.0
2003	7.7	52.6	39.7
2004	7.3	53.8	39
2005	6.6	53.3	40
2006	5.9	54.1	40.1
2007	5.3	54	40.7
2008	5.1	53.9	41

Source: CHINA STATISTICAL YEARBOOK (2000-2009).

With regard to agricultural production, Zhejiang has historically been famous for its rice production. The cropping structure figure (Table 5-2) shows that grain production in Zhejiang mainly concentrates on rice, accounting for above 60 % of the total sown area. The main cash crop is rapeseed, which accounts for 8 % of total sown areas. For the past eight years, the amount of vegetables grown have increased in Zhejiang; they occupied 15 % of the total sown area in 2002.

Table 5-2: Cropping structure in Zhejiang province (1995-2002)

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Grain crops	75%	74%	73%	70%	74%	67%	70%	65%
Wheat	0%	0%	0%	1%	1%	1%	0%	0%
Rice	71%	69%	69%	65%	70%	64%	66%	59%
Corn	0%	0%	0%	0%	1%	1%	1%	1%
Soybean	1%	1%	1%	1%	1%	2%	2%	2%
Cash crops	8%	7%	7%	7%	8%	9%	11%	12%
Cotton	1%	1%	1%	1%	0%	0%	1%	0%
Rapeseed	6%	6%	6%	6%	7%	8%	8%	6%
Sugar	0%	0%	0%	0%	0%	0%	0%	5%
Fiber	0%	0%	0%	0%	0%	0%	0%	0%
Tobacco	0%	0%	0%	0%	0%	0%	0%	0%
Other crop	17%	19%	19%	23%	18%	23%	19%	22%
Vegetables	7%	7%	9%	13%	12%	16%	14%	15%

Source: RCRE (1995-2002).

Note: Here we use RCRE data to calculate cropping structure due to its simple classification.

Rice productivity, as shown in Table 5-3, has increased 35 % over the past nine years (1999-2008), amounting to 7000 kg/ha in 2008. Rapeseed productivity, which was the most important cash crop in Zhejiang, also increased 17 % from 1999 to 2008. Corn productivity improved greatly, although it only accounted for 1 % of the total sown areas in our database. The multiple cropping index[4] of farm crops in Zhejiang is 167.23 % (CHINA AGRICULTURE YEARBOOK, 2001).

[4] Multiple cropping is the practice of growing two or more crops in the same space during a single growing season; the multiple cropping index indicates cropping intensity, with more than 100% indicating that the crops are harvested more than one season per year.

Table 5-3: Productivity in Zhejiang province (1999-2008)

Field crop	*Productivity (tons/ha)*			
	1999	*2002*	*2005*	*2008*
Grain				
Wheat	2.8	2.7	3.2	3.9
Rice	5.8	6.7	6.3	7.0
Corn	3.6	4.3	4.1	4.3
Soybean	2.1	2.3	2.3	2.4
Cash crops				
Cotton	1.1	1.2	1.2	1.4
Rapeseeds	1.8	1.6	2.0	2.1
Sugar	59.2	61.7	57.3	61.3
Fiber	2.7	2.9	2.4	4.2
Tobacco	2.0	2.3	2.2	2.7
Other crops				
Vegetable	27.3	25.6	26.5	28.4

Source: CHINA AGRICULTURE YEARBOOK (2000-2009).

The development of agricultural infrastructure, especially irrigation usage, is very important for agricultural production. Irrigation usage in Zhejiang is indicated by the percentage of the usage of irrigation system, which can be seen in Table 5-4. Generally, irrigation has improved, and effective irrigation covers nearly 50 % of the total cultivated land until 2007. The effective irrigated percentage went up suddenly due to a sharp decrease of total cultivated land in this province in 2007[5].

Table 5-4: Percentage of arable land irrigated in Zhejiang (2000-2007)

Year	*Effectively irrigated percentage*	*Mechanical pumping percentage*
2000	0.64	0.48
2001	0.64	0.47
2002	0.64	0.47
2003	0.65	0.47
2004	0.65	0.47
2005	0.64	0.47
2006	0.65	0.46
2007	0.73	0.50

Source: Author's calculation based on China's agriculture yearbook (2001-2008).

Chemical fertilizer has been widely used in Chinese agricultural production to maintain high production. For the Zhejiang province, the total amount of fertilizer usage varies, with total fertilizer input being 928,000 tons in 2007, as shown in Table 5-5. Among fertilizers, the share of nitrogenous fertilizer accounted for

[5] The China Agriculture Yearbook did not update the statistical data for cultivated land from 2000 to 2006.

approximately two-thirds of the total chemical fertilizer usage, but has started to decrease gradually, and the share of compound fertilizer has increased. However, the usage of Phosphate, which may promote agricultural productivity in the long term, has not increased.

Table 5-5: Chemical fertilizer usage in Zhejiang (1999-2007, unit: 10,000 tons)

Year	*Total*	*Nitrogenous*	*Phosphate*	*Potash*	*Compound*
1999	92.7	61.9	12.7	5.7	12.4
2000	89.7	59.7	12.2	5.8	12.1
2001	90.3	57.3	12.4	6.6	14.1
2002	91.9	56.8	12.5	7.4	15.2
2003	90.4	53.9	12.2	7.6	16.7
2004	93.3	55.3	12.9	8	17.1
2005	94.3	56.1	12.6	7.5	18.1
2006	94	55.4	12.2	7.7	18.6
2007	92.8	53.9	12	7.8	19.1

Source: RURAL STATISTICAL YEARBOOK OF CHINA (2000-2008).

5.1.2 Hubei

Hubei lies in the middle of China, and the Jianghan Plain takes up most of central and eastern Hubei, accounting for 20 % of Hubei's total area, while the west and the peripheries are more mountainous. Hubei has a subtropical climate with 4 distinct seasons. The average temperatures range between 1-6 degrees Celsius in winter and 24-30 degrees Celsius in summer. However, the highest temperature exceeds 40 degrees Celsius in the Jianghan Plain. The average yearly rainfall is between 800~1600 mm and average yearly sunlight is 1150~2245 hours. The frost-free season lasts between 230~300days (WIKIPEDIA, 28 Oct. 2010).

The Hubei province is one of the most important agricultural regions; its main agricultural products include rapeseed, rice, wheat, and tea. The GDP in Hubei ranked twelfth of provinces in China in 2008, and the primary sector accounted for less than 16 % of total GDP in Hubei, as reported in Table 5-6. The importance of the tertiary sector in Hubei also increased greatly, accompanied with the decrease of the share of the secondary sector, and it has achieved 41 % of Hubei's GDP in 2008.

Table 5-6: Structure of GDP in Hubei province (1999-2008)

Year	*Primary sector (%)*	*Secondary sector (industry) (%)*	*Tertiary sector (services) (%)*
1999	17.0	48.9	34.1
2000	15.5	49.7	34.9
2001	14.8	49.6	35.5
2002	14.2	49.2	36.6
2003	14.8	47.8	37.4
2004	16.2	47.5	36.4
2005	16.6	43.1	40.3
2006	15	44.4	40.6
2007	14.9	43	42.1
2008	15.7	43.8	40.5

Source: CHINA STATISTICAL YEARBOOK (2000-2009).

The cropping structure is shown in the following table (Table 5-7). Hubei's main grain products are quite diversified, but rice is still the most important product, accounting for about 40 % of total sown areas. The second most important crop is wheat, but with a decreasing share. Rapeseed was the most important cash crop, amounting to 20 % of the total sown area in 2002, while vegetable cultivation did not increase significantly.

Table 5-7: Cropping structure in Hubei province (1995-2002)

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Grain crops	74%	75%	75%	73%	72%	67%	66%	64%
Wheat	16%	17%	18%	18%	16%	15%	13%	11%
Rice	41%	42%	41%	39%	39%	36%	36%	36%
Corn	6%	6%	6%	7%	8%	7%	8%	8%
Soybean	3%	3%	3%	3%	3%	4%	4%	4%
Cash crops	20%	19%	17%	19%	20%	23%	24%	25%
Cotton	7%	6%	6%	5%	5%	5%	4%	4%
Rapeseed	13%	12%	11%	12%	15%	18%	19%	20%
Sugar	0%	0%	0%	0%	0%	0%	0%	0%
Fiber	0%	0%	0%	0%	0%	0%	0%	0%
Tobacco	0%	0%	0%	0%	0%	0%	0%	0%
Other crop	6%	7%	7%	8%	8%	10%	10%	11%
Vegetables	5%	5%	6%	5%	5%	7%	6%	8%

Source: RCRE (1995-2002).

Generally, grain productivity has increased over the past nine years (1999-2008), as shown in Table 5-8. Wheat productivity has increased by 18 %, and rice productivity has increased by 5 % from 1999 to 2008. Regarding cash crops, rapeseed productivity has also increased by 18 % for the past nine years (1999-2008). The multiple cropping index of farm crops in Hubei is 153.22 % (CHINA AGRICULTURE YEARBOOK, 2001).

Table 5-8: Productivity in Hubei province (1999-2008)

Field crop	*Productivity (tons/ha)*			
	1999	*2002*	*2005*	*2008*
Grain				
Wheat	2.8	2.2	2.9	3.3
Rice	7.4	7.6	7.4	7.8
Corn	4.4	4.8	5.0	4.8
Soybean	2.1	2.0	2.4	2.3
Cash crops				
Cotton	0.9	1.1	1.0	0.9
Rapeseeds	1.6	1.3	1.9	1.9
Sugar	48.9	47.9	42.9	40.0
Fiber	2.8	2.3	2.1	2.0
Tobacco	1.8	1.8	1.9	1.9
Other crops				
Vegetable	29.1	28.5	29.0	28.5

Source: CHINA AGRICULTURE YEARBOOK (2000-2009).

For the past nine years (1999-2008), the effective irrigation percentage calculated from effective irrigated area divided by the total cultivated area has increased modestly in Hubei. Before 2007, 40 % of the cultivated land had been irrigated effectively (see Table 5-9).

Table 5-9: Percentage for arable land irrigated in Hubei (2000-2008)

Year	*Effective irrigated percentage*	*Mechanical pumping percentage*
2000	0.38	0.58
2001	0.38	0.25
2002	0.38	0.25
2003	0.36	0.24
2004	0.39	0.23
2005	0.41	0.24
2006	0.40	0.24
2007	0.42	0.24
2008	0.42	0.23

Source: Author's calculation based on CHINA AGRICULTURE YEARBOOK (2001-2009).

The total amount of nitrogenous fertilizer usage from 1999 to 2007 in Hubei increased greatly, up 19 % since 1999. This might indicate that the productivity increase in Hubei still depended on an increase of fertilizer usage (see Table 5-10). Among fertilizers, the total amount of nitrogenous fertilizer increased, while the total amount of phosphate usage did not. At the same time, the total amount of compound fertilizers has also increased.

Table 5-10: Chemical fertilizer usage in Hubei (1999-2007, unit: 10,000 tons)

Year	*Total*	*Nitrogenous*	*Phosphate*	*Potash*	*Compound*
1999	251.5	128.2	62.6	16.8	44
2000	247.1	132.7	52.5	16.2	45.7
2001	245.3	126.8	54.6	17.5	46.4
2002	257	133.1	56.8	19.4	47.7
2003	270.3	136.9	61.6	21.2	50.7
2004	281.9	142.5	62.7	22	54.8
2005	285.8	142	59.8	23.2	60.8
2006	292.5	140.5	63.7	24.2	64.1
2007	299.9	142.8	63.5	24	69.6

Source: RURAL STATISTICAL YEARBOOK OF CHINA (2000-2008).

5.1.3 Yunnan

Yunnan is largely covered by mountains (hills cover 94 % of the province), especially in its north and west, with an average altitude of 1,980m. Yunnan is famous for its nice climate of "four springs" in a year. The average temperatures in January range from 8-17 degrees Celsius; July averages vary from 21-27 degrees. The average annual rainfall ranges from 600~2300 mm, with over half of the rain occurring between June and August (WIKIPEDIA, 28 Oct. 2010).

Yunnan is one of the less developed provinces in China; its GDP ranked 23rd of provinces in 2008. More than 18 % of Yunnan's GDP came from the primary sector between 1999-2008, as shown by Table 5-11.

Table 5-11: Structure of GDP in Yunnan province (1999-2008)

Year	*Primary sector (%)*	*Secondary sector (industry) (%)*	*Tertiary sector (services) (%)*
1999	22.2	44.5	33.3
2000	22.3	43.1	34.6
2001	21.7	42.5	35.8
2002	21.1	42.6	36.3
2003	20.4	43.4	36.2
2004	20.4	44.4	35.2
2005	19.3	41.3	39.5
2006	18.7	42.7	38.5
2007	17.7	43.3	39.1
2008	17.9	43	39.1

Source: CHINA STATISTICAL YEARBOOK (2000-2009).

Farmers in Yunnan plant a large amount of grain, which accounts for approximately 90 % of the total sown area, as shown in Table 5-12. Among crops, rice still leads, making up nearly 30 % of the total sown area, while wheat and corn cover less than 40 % of sown area. Cash crops are rarely planted compared to Zhejiang and Hubei, encompassing only about 5 % of the total sown area; most of the cash crop is tobacco.

Table 5-12: Cropping structure in Yunnan province (1995-2002)

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Grain crops	86%	85%	83%	85%	87%	92%	92%	91%
Wheat	15%	17%	14%	14%	21%	18%	18%	18%
Rice	30%	28%	30%	27%	28%	28%	27%	27%
Corn	17%	17%	14%	18%	17%	18%	18%	19%
Soybean	2%	2%	3%	5%	4%	5%	4%	4%
Cash crops	5%	5%	7%	4%	3%	3%	1%	2%
Cotton	0%	0%	0%	0%	0%	0%	0%	0%
Rapeseed	1%	0%	0%	0%	1%	1%	1%	1%
Sugar	0%	0%	0%	0%	0%	0%	0%	0%
Fiber	0%	0%	0%	0%	0%	0%	0%	0%
Tobacco	4%	4%	6%	4%	2%	1%	0%	1%
Other crop	9%	11%	10%	10%	10%	5%	7%	7%
Vegetables	2%	2%	2%	3%	4%	4%	4%	4%

Source: RCRE (1995-2002).

Grain productivity in this province has not improved significantly (except for soybeans) over the past nine years (1999-2008), as shown in Table 5-13. Indeed, soybean productivity has increased by two-thirds since 1999, and has increased to 2,000kg/ha in 2008. Cotton and fiber productivity in Yunnan greatly improved from 1999 to 2008, and amounted to 900kg/ha and 4,700kg/ha, respectively in 2008. Unfortunately, the total planted area in the province is less than 1 %. The multiple cropping index of farm crops in Yunnan is 90.11 % (CHINA AGRICULTURE YEARBOOK, 2001).

Table 5-13: Productivity in Yunnan province (1999-2008)

	Productivity (tons/ha)			
	1999	*2002*	*2005*	*2008*
Grain				
Wheat	2.2	2.2	2.0	2.0
Rice	6.1	5.0	6.2	6.1
Corn	4.0	4.1	3.8	4.0
Soybean	1.2	1.3	1.4	2.0
Cash crops				
Cotton	0.4	0.4	0.4	0.9
Rapeseeds	1.5	1.7	1.7	1.6
Sugar	53.2	58.3	55.5	61.3
Fiber	0.8	2.8	5.2	4.7
Tobacco	1.9	2.0	2.0	2.2
Other crops				
Vegetable	18.1	19.8	19.7	20.0

Source: CHINA AGRICULTURE YEARBOOK (2000-2009).

Irrigation in the Yunnan province improved very modestly from 1999 to 2002. Until 2007, there only 22 % of total cultivated land was irrigated effectively, as shown in Table 5-14.

Table 5-14: Percentage of arable land irrigated in Yunnan (1999-2007)

Year	*Effectively irrigated percentage*	*Mechanical pumping percentage*
1999	0.19	0.03
2000	0.19	0.03
2001	0.19	0.03
2002	0.20	0.03
2003	0.20	0.03
2004	0.20	0.03
2005	0.20	0.03
2006	0.21	0.03
2007	0.22	0.03

Source: Irrigation percentage is from the author's own calculations, based on China Agriculture Yearbook (2000-2008).

The total amount of fertilizer usage in Yunnan has increased greatly, with an average increase of 6 % per year from 1999 to 2008 indicating an increasing capital input in agricultural production. It is worth noting that the total amount of compound fertilizer usage doubled and the amount of phosphate usage also increased by 62 % in the past nine years.

Table 5-15: Chemical fertilizer usage in Yunnan (1999-2007, unit:10,000 tons)

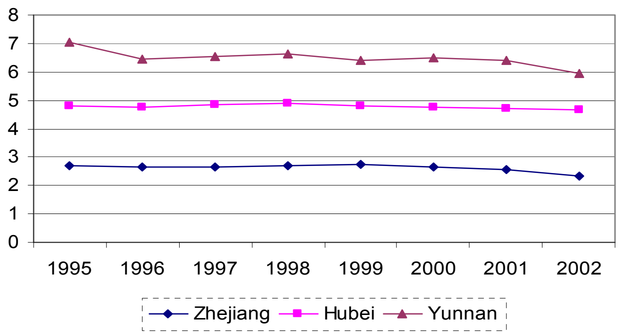
1	Total	Nitrogenous	Phosphate	Potash	Compound
1999	90.5	52.9	15.3	7.8	14.5
2000	112.1	66.1	18.3	9.1	18.5
2001	120	70.1	19.9	9.7	20.2
2002	125	72.2	21.7	9.9	21.2
2003	12.92	74.5	21.5	10.4	22.8
2004	137.2	78.8	22.7	11.2	24.6
2005	142.7	79.9	22.7	12	28
2006	150.4	83.2	23.8	12.8	30.6
2007	158.3	86.6	24.8	13.6	33.2

Source: RURAL STATISTICAL YEARBOOK OF CHINA (2000-2008).

5.2 Farm size and degree of land fragmentation

The average farm size for Zhejiang, Hubei and Yunnan provinces is depicted in Figure 5-1. Generally, the average farm size decreases year-to-year; it is less than 3 mu in Zhejiang. This number is much larger in Hubei, at approximately 5 mu. Yunnan has the largest average farm size among the three provinces, at more than 6 mu; however, most farms are located in mountainous areas.

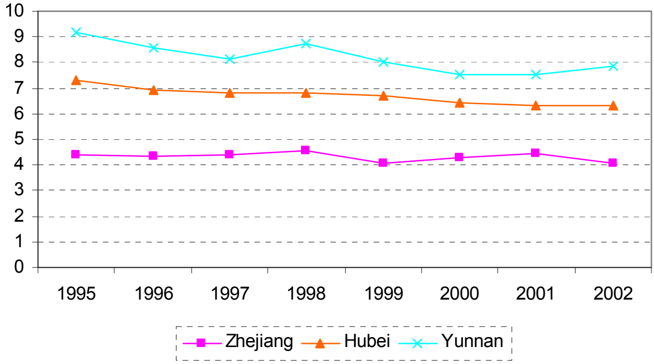
Figure 5-1: Average farm size in Zhejiang, Hubei and Yunnan provinces (1995-2002)



Source: Author's calculation based RCRE (1995-2002).

Land fragmentation is still a widespread phenomenon, as illustrated in Figure 5-2. The average number of plots per farm has decreased overall but not significantly, while the degree of land fragmentation is lowest in Zhejiang among the three, and highest in Yunnan, at approximately 8 plots per farm.

Figure 5-2: Land fragmentation degree (1995-2002, unit: plot)



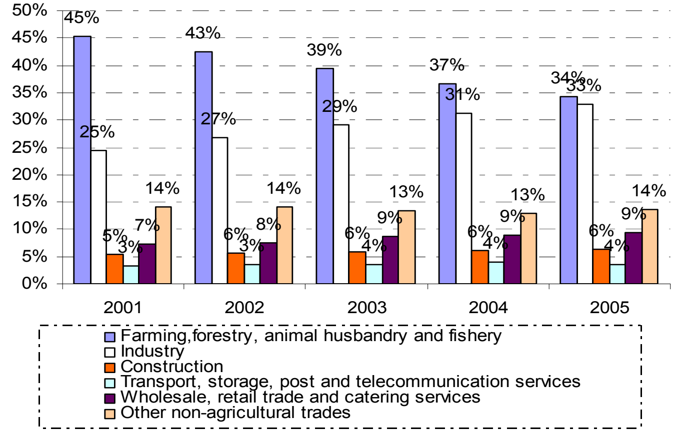
Source: Author's calculation based RCRE (1995-2002).

5.3 The employment of rural laborers

5.3.1 Rural employment structure

The rural employment structure in Zhejiang, Hubei and Yunnan provinces is depicted in the following. The share of agricultural employment decreased by 7.3 % per year in Zhejiang; ultimately, the share of agricultural employment nearly equaled that of industry in 2005, as shown in Figure 5-3. Approximately 14 % of rural employment pursued other non-agricultural trades from 2001 to 2005, while employment in other industries did not change noticeably. Nevertheless, the figures show that the labor market in Zhejiang has developed very quickly and improved greatly.

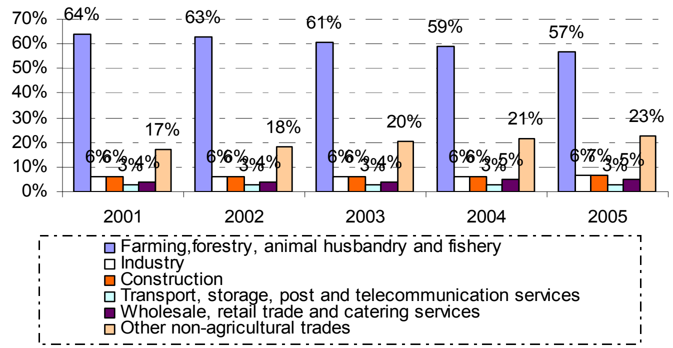
Figure 5-3: Rural employment structure in Zhejiang



Source: CHINA AGRICULTURE YEARBOOK (2002-2006).

From 2001-2005, agricultural employment decreased at a rate of 3 % per year in Hubei, but approximately 60 % of rural employment still took place on farms, as depicted in Figure 5-4. The largest non-agricultural activity was non-agricultural trades in this region, which supplied work opportunities equaling 23 % of rural employment in 2005. However, employment in other industries such as industry, construction and services was still underdeveloped, and the share of employment did not noticeably improve from 2001 to 2005.

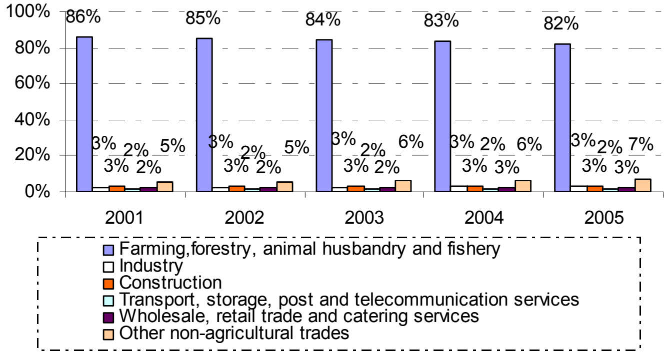
Figure 5-4: Rural employment structure in Hubei



Source: CHINA AGRICULTURE YEARBOOK (2002-2006).

Generally, the rural employment structure in Yunnan did not change significantly, indicating the slow development of the labor market in this region, as depicted in Figure 5-5. The share of agricultural employment decreased 4 % from 2001-2005, while the share of non-agricultural trades increased 2 %. In 2005, more than 80 % of rural employment still took place in the agricultural industry.

Figure 5-5: Rural employment structure in Yunnan



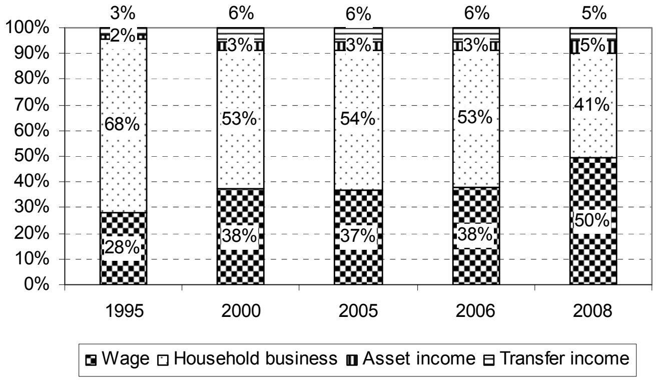
Source: CHINA AGRICULTURE YEARBOOK (2002-2006).

5.3.2 Rural income structure

It has been found that employment in local village and township-run enterprises, family businesses, and long-term employment outside the village increased from 107.4 persons to 210.1 persons from 1988-1995 (BRANDT et al., 2004). Afterwards, non-agricultural income started to increase after the stagnation of agricultural growth. However, this growth is quite unevenly developed from the east to the west. To better reveal the evolution of the rural income structure, a longer time period will be covered in this section.

As seen in the following graphs, the share of household business income began to decrease in 1995, accompanied by an increased share of wage income, though it remained stable in Zhejiang after 2000. At the end of 2008, household business incomes only accounted for 50 % of the total income of rural households.

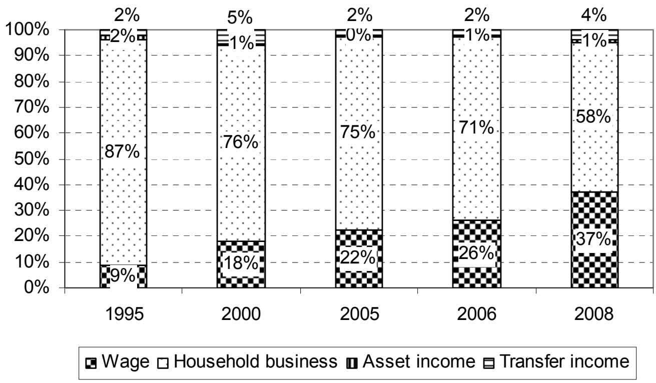
Figure 5-6: Income structure of rural households in Zhejiang



Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007-2009).

Compared to Zhejiang, off-farm opportunities began to increase later in Hubei, and there were still a number of farmers that mainly depended on household business income. The share of wage income started to boom after 1995, and it achieved 26 % of the total income in 2006. By the end of 2008, the share of wage income was 37 % (see Figure 5-7).

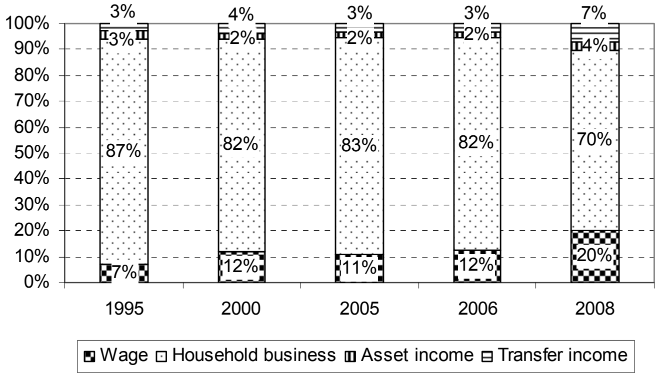
Figure 5-7: Income structure of rural households in Hubei



Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007-2009).

Yunnan is an even less developed province, as the change of the rural income structure for the past 10 years shows in Figure 5-8. More than 80 % of the rural income came from household businesses in this province, with its wage only accounting for 12 % at the end of 2006. However, structural change began to occur for incomes in recent years, and the share of household business has fallen by 15 % in two years (2006-2008).

Figure 5-8: Income structure of rural households in Yunnan

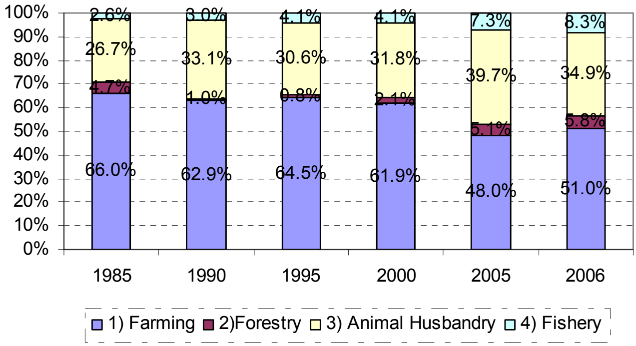


Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007-2009).

Household business income not only includes farming, but also includes other self-employed household work, which is closely correlated with the development of the labor market and off-farm opportunities as well. Hence, it is necessary to further explore the structure of household business in three provinces further.

Regarding household business income, its structure also experienced various changes in three provinces. The percentage of farming income has fallen for the past 21 years, and accounted for 51 % of the total household business in Zhejiang at the end of 2006 (see Figure 5-9).

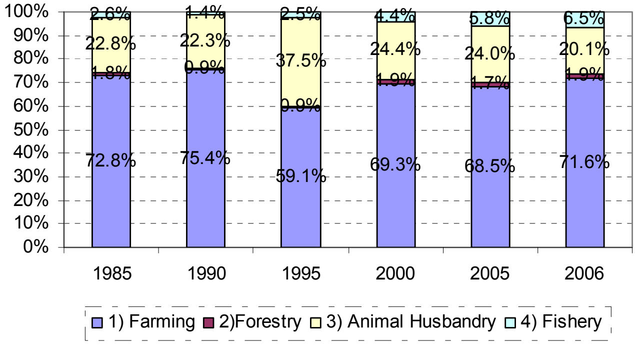
Figure 5-9: Household business structure in Zhejiang



Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007).

The share of farming income in Hubei fell from 1985-1995, though it rose afterwards (see Figure 5-10). The development of the labor market contributed to diversify household income and increased the opportunities of participation into the other work in Hubei. However, positive agricultural policies such as the impletion of agricultural subsidies and the exemption of agricultural tax have motivated farmers to put more efforts into agricultural production since 2000, wherefrom farming income still constituted an important part of rural household business in Hubei, taking up more than 70 % of household business income in 2006.

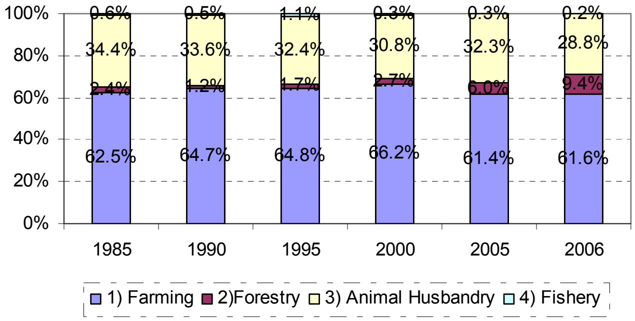
Figure 5-10: Household business structure in Hubei



Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007).

The same applies to the evolution pattern of income structure, though the evolution pattern of household business in Yunnan province did not change a great deal from 1985-2006. Farming income accounted for 62.5 % of household business in 1985, and this number was still 61.6 % at the end of 2006, indicating that off-farm opportunities for rural laborers did not noticeably improve during these years.

Figure 5-11: Household business structure in Yunnan



Source: CHINA YEARBOOK OF HOUSEHOLD SURVEY (2007).

5.4 Data cleaning strategy

This section seeks to clarify the approaches to data cleaning in the thesis, which is comprised of two parts: an introduction of the data source and an elaboration of the data cleaning strategy and outlier control.

5.4.1 Introduction of the database

The database used in the monograph came from the three Chinese provinces of Zhejiang, Hubei and Yunnan. The survey was conducted by the Rural Survey Team of the Research Centre for Rural Economy in the Ministry of Agriculture in China (RCRE). The empirical study is based on a panel data set covering 9 villages in Zhejiang, 15 villages in Hubei, and 5 villages in Yunnan from 1995 to 2002. Zhejiang is one of the most developed provinces, where land, labor, insurance and credit markets are more developed compared to its counterparts; Hubei is one of the most important agricultural provinces; and Yunnan is a less developed province in the west of China.

5.4.2 Data cleaning and outlier control

One important issue when cleaning our panel data is to identify whether the household is consistent with the one investigated in the previous year, which requires identifying the panel data. Two situations might occur during the survey: one is that the interviewed household is not able to be found, requiring that a new household be chosen to replace it without allocating a new household code; another situation is that the subfamily takes the place of the interviewed family. Theoretically, a new household code should be allocated to indicate a different household for both cases. However, it was not totally dealt with like this in our database, and a further cleaning of data was implemented.

First, we identified whether the household had been changed or not by using one variable regarding whether this household had been surveyed during the previous year in our database; if this was not the case, the household was allocated a new household code. However, this variable could not distinguish whether the household was separated into two subfamilies. The age of the main laborer in the family and the family size are employed to identify whether or not it is a subfamily. When the age difference is not continuous and a reduction of family size is more than one person, the subfamily is regarded as a new household and a new household code was allocated.

The structural change of panel data structure is illustrated in the following graph (Figure 5-12). The left part is the panel data structure for the original database, while the right part is the one we have cleaned. The first column of each table indicates the frequency of the database with the pattern on the fourth column; the second column is the percentage of the corresponding pattern, and the third is the cumulative percentage of the pattern. From the graph we find that the number and share of the full panel data are reduced after data cleaning from 1,283 to 1,253, accounting for 67.28 % and 64.29 % of total observations, respectively, and the incomplete panel data are increased.

Figure 5-12: Structure of panel data before and after data cleaning

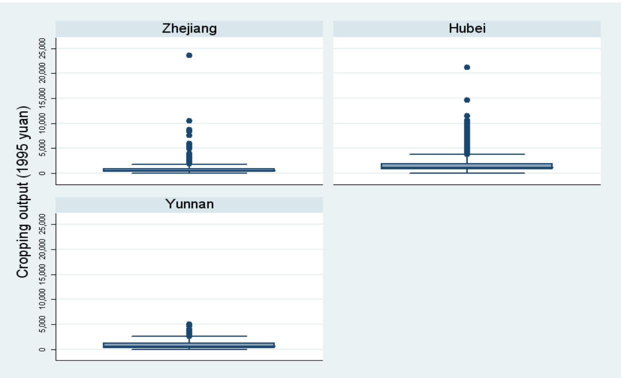
Freq.	Percent	Cum.	Pattern
1283	67.28	67.28	11111111
57	2.99	70.27	1111111.
56	2.94	73.20	11......
48	2.52	75.72	1111....
46	2.41	78.13	..111111
38	1.99	80.13	111111.1
37	1.94	82.07	11111...
36	1.89	83.95	111111..
29	1.52	85.47	1111
277	14.53	100.00	(other patterns)
1907	100.00		XXXXXXXX

Freq.	Percent	Cum.	Pattern
1253	64.29	64.29	11111111
67	3.44	67.73	1111111.
64	3.28	71.01	11......
50	2.57	73.58	..111111
50	2.57	76.14	1111....
40	2.05	78.19	111111..
38	1.95	80.14	11111...
37	1.90	82.04	111111.1
34	1.74	83.79	1
316	16.21	100.00	(other patterns)
1949	100.00		XXXXXXXX

Source: RCRE (1995-2002).

Another important issue for the database is the outlier control, which helps improve the quality of data in the empirical study, and is especially essential when we want to eliminate data input mistakes and a check of data source is impossible. An outlier is a data point which is distant from the main body (say, the middle 50 %) of the data (MUKHERJEE et al., 1998, p. 87; PETRICK, 2004, p. 143). The Interquartile Range (IQR) is frequently applied to detect outliers in an econometrics approach. A data point below 1.5 times the IQR of the lower quartile is considered to be the lower outlier, while above 1.5 times the IQR of the upper quartile is considered to be the upper outlier. A data point below 3 times the IQR of the lower quartile is considered to be the lower far-outlier, and above 3 times the IQR of the upper quartile is considered to be the upper far-outlier. The box plot (see Figure 5-13) in the following gives us an example of outlier control and IQRs for the cropping output for three provinces.

Figure 5-13: Box plot of cropping output



Source: RCRE (1995).

Note: Dots are the outliers and the horizontal line denotes the outlier.

Considering the large variations within and between provinces for each variable in our database, we use a far-outlier in each province as a standard to delete outliers with respect to the output value, the labor input, the land input, the capital input and the number of plots. Finally, 1,176 observations are deleted as outliers in the total 13,141 observations.

5.5 Conclusions

This chapter laid out the characteristics of agricultural production, farm structure and degree of land fragmentation, rural labor market development in the Zhejiang, Hubei and Yunnan provinces, and discussed the data cleaning strategy in the monograph. The following two chapters will estimate models with this database, and a description of data with respect to specific variables in empirical studies will be presented.

6 THE EFFECT OF LAND FRAGMENTATION ON AGRICULTURAL LABOR PRODUCTIVITY

The theoretical analysis in chapter 3 shows that the effect of land fragmentation on agricultural labor productivity, depending on the local shape of the production function, is undetermined *a priori*. This chapter is concerned with estimating the effect of land fragmentation on agricultural labor productivity by using the empirical methodologies mentioned in chapter 4. The chapter is structured as follows: studies on the effect of land fragmentation on agricultural production are reviewed in section 6.1; the database is introduced in section 6.2; the empirical strategy is presented in section 6.3; the results are reported in section 6.4; conclusions are drawn in section 6.5.

6.1 An overview of the effect of land fragmentation on agricultural production

Research on agricultural development in China has increasingly focused on the potentially negative effects of highly fragmented farm structures. In China, land fragmentation emerged as a result of land redistribution in the aftermath of the HRS implemented in the late 1970s. Various researchers pointed out that land fragmentation was causing productivity losses (NGUYEN et al., 1996; WAN and CHENG, 2001; FLEISHER and LIU, 1992). It is therefore implied that a consolidation of farmland may contribute to increased levels of agricultural productivity.

However, the effect of land fragmentation may not only be adverse, and land fragmentation could not only have impacts on agricultural output, but also on the marginal product of input. The most important input in Chinese agriculture, next to land, is labor. Based on an analysis of labor costs in Chinese farm households, TAN et al. (2008) suggest that more liberal land policies that allow consolidation may release more agricultural surplus labor in the future. If this is true, policies addressing land fragmentation will also affect the steadily increasing number of off-farm employees and rural migrants, and thus one of the most challenging problems of Chinese economic transition.

There is some limited evidence available in the literature on the output and labor allocation effects of land fragmentation. Based on a CD production function, FLEISHER and LIU (1992) estimated that land fragmentation led to inefficiency in agricultural production. This result was confirmed by NGUYEN et al. (1996), who found that there was a positive relationship between plot size and output for major grain crops in China. While TAN et al. (2008) find that fragmented farm structures correlate with higher labor costs, it is not entirely clear why this implies that land consolidation does release rural labor, as the authors do not investigate the actual mechanisms of labor allocation any further.

Moreover, other empirical work based on the analysis of household data provides only indirect and mixed evidence on the linkages between land fragmentation and the off-farm labor supply in rural China. WANG et al. (2007) found positive effects of village land-renting activities, which imply a higher potential for voluntary land consolidation, on household decisions to participate in the off-farm labor market in Zhejiang province. This evidence supports the suggestion by TAN et al. (2008). However, there was no effect on the quantity of households' off-farm labor supply. WAN and CHENG (2001), by using a flexible translog function with non-constant elasticities of substitution, report that more plots per household increase the marginal product of labor in maize and early rice production (the estimated β_2 parameters in table 5 of their paper), thus implying lower on-farm labor demand if land is consolidated. However, they found the opposite sign for tuber production. Furthermore, they paid more attention to scale economies and did not illustrate the heterogeneous effect of land fragmentation on agricultural inputs nor the reason for it. In addition, CARTER and YAO (2002) found that more land parcels per farm reduce the average labor intensity on-farm in a sample of farmers from Jiangxi and Zhejiang provinces, which contradicts TAN et al. (2008). Similarly, BROSIG et al. (2007) show that, in Zhejiang villages with much activity on the land rental market, households display a lower tendency to engage in off-farm labor markets. The aim of this monograph is to gain some insights into the effects of fragmentation on the off-farm labor supply in a more direct way than in the existing literature. In a microeconomic perspective, the key determinant of off-farm employment decisions of a rural household is the on-farm MPL (see section 3.1, p. 25). Based on these insights, we provide an empirical analysis of the fragmentation effect on agricultural labor productivity in this chapter. Our theoretical argument is that how land fragmentation affects the MPL and off-farm labor supply is undetermined *a priori* (see section 3.1, p. 25; section 3.2, p. 28).

6.2 Data description

Household-level panel data comprises the value of agricultural outputs and inputs. We create a composite output variable by summing up the output of all produced crops, including those consumed by the households themselves. Average unit values at the provincial level in 1995 prices are used as aggregation devices. We used the consumer price index for rural areas as published by the Chinese statistical office to deflate all monetary values. We distinguish between three types of inputs, labor L, capital K, and land A, plus the number of plots N as a measure of α. The inputs include farm size measured in mu, labor input measured in days per person and capital inputs measured in 1995 yuan. A description of the database for eight years is shown in Table 6-1. The average farm size decreased from 4.98 mu to 4.67 mu from 1995 to 2002, and the average farm size for all years was 4.85 mu. The average labor input also experienced a decrease for the past eight years with the increase of off-farm opportunities (See section 5.3, p. 53), and the overall average labor input is 238 person days. The average capital input increased, achieving more than 620 yuan in 1997. However, this rate started to decrease afterwards, and reverted to its 1995 level in 2002. Generally, the degree of land fragmentation has fallen in the past eight years, though very slowly, and the average number of plots was 6.26 in 2002.

Table 6-1: Description of Database (1995-2002)

Variables	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
	1995		*1996*		*1997*	
Value of Output (yuan)	1332.54	992.57	1282.73	974.76	1177.01	919.76
Labor (person days)	239.27	161.66	242.78	164.19	245.96	167.66
Capital (yuan)	560.42	407.67	627.72	463.80	621.23	452.13
Land (mu)	4.98	3.89	4.74	3.71	4.96	4.03
Number of plots	7.22	5.35	6.84	5.06	6.84	5.17
Number of observations	1,577		1,560		1,568	
Year	*1998*		*1999*		*2000*	
Value of Output (yuan)	1057.74	823.41	925.23	808.22	859.16	730.54
Labor (person days)	240.99	155.98	237.25	159.21	228.18	146.29
Capital (yuan)	588.12	422.90	566.44	405.89	541.33	387.63
Land (mu)	4.89	3.77	4.89	3.95	4.84	3.69
Number of plots	6.74	5.06	6.46	4.72	6.40	4.62
Number of observations	1,555		1,500		1,497	
Year	*2001*		*2002*		*Total*	
Value of Output (yuan)	834.97	777.77	682.86	643.39	1026.87	872.15
Labor (person days)	240.95	158.41	224.02	150.11	237.61	158.34
Capital (yuan)	544.92	379.29	558.20	400.23	576.82	417.67
Land (mu)	4.83	3.67	4.67	3.67	4.85	3.80
Number of plots	6.43	4.58	6.26	4.58	6.66	4.92
Number of observations	1,435		1,412		12,104	

Source: RCRE (1995-2002), all monetary values are in 1995 prices.

6.3 Functional form

The major aim of the econometric analysis in this chapter is to provide an unbiased estimate of the effect of land fragmentation on labor productivity. The strategy used here is to estimate a flexible production function that takes into account the number of plots per farm as a measure of land fragmentation.

Previous studies have used CD production functions to estimate the impact of land fragmentation (NGUYEN et al., 1996; FLEISHER and LIU, 1992). In order to estimate a partial effect of land fragmentation on marginal labor productivity, a more flexible approach is needed that allows interactions among factors. We therefore employ a translog function, which extends the CD by both interaction and square terms of the factors.

Given the three conventional inputs plus the number of plots as arguments, the translog function with land fragmentation can be expressed as follows:

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln A_{it} + \beta_4 \ln N_{it} + \beta_5 \ln N_{it} \ln L_{it} \\ &+ \beta_6 \ln N_{it} \ln A_{it} + \beta_7 \ln A_{it} \ln K_{it} + \beta_8 \ln L_{it} \ln K_{it} + \beta_9 \ln N_{it} \ln K_{it} \\ &+ \beta_{10} \ln L_{it} \ln A_{it} + \beta_{11} (\ln L_{it})^2 + \beta_{12} (\ln K_{it})^2 + \beta_{13} (\ln A_{it})^2 + \beta_{14} (\ln N_{it})^2 + u_{it}\end{aligned} \quad , \text{(6-1)}$$

where u_{it} is an i.i.d. error term, and K indicates all capital input. Therefore, N is allowed to affect all marginal products of inputs.

The direct effect of land fragmentation on agricultural production is β_4, which is supposed to be negative according to equation (6-1). WAN and CHENG (2001) and NGUYEN et al. (1996) report regression estimates that support this assumption. If $\beta_4 = \beta_5 = \beta_6 = \beta_9 = 0$, land fragmentation has a zero impact on the marginal product of inputs, otherwise, the impact of land fragmentation is undetermined. The effect of land fragmentation on labor is β_5 which will be determined by the local shape of the production function. When β_5 is positive, it indicates that the MPL on fragmented land is higher than that on consolidated land at the same amount of every input. When β_5 is negative, it indicates that the MPL on fragmented land is lower. As this parameter is of prime interest in our analysis, we attempt to estimate (6-1) in the following.[6]

---

[6] A commonly used approach in the literature is to estimate agricultural technology based on a dual specification. Sometimes, the production function is taken as a starting point, but more frequent is the use of profit or cost functions (CAPALBO and ANTLE, 1988). Estimation is typically based on the derived set of input share equations, which will depend on input quantities in the case of a production function, and on input prices and output quantities or prices in the cases of cost and profit functions (see CAPALBO, 1988 for a summary, and BERNDT, 1991, chapter 9, for further technical detail and literature). As we are interested in recovering the parameter β_5 of the production function in (6-1), dual specifications of profit or cost functions that do not include this parameter are of little help. While a modified system

To ease the interpretation of coefficients in the translog model, all variables were demeaned after taking logs, so that the estimates of β_1 to β_4 are the production elasticities of the factors at geometric sample means (see section 4.5, p. 41, for more details).

6.4 Empirical study and results

6.4.1 Estimating strategy

We focus on the estimation of the production function, and report the results that are robust to unobserved heterogeneity and the correlation of data between households within the same village. As discussed in chapter 4, the FE model is supposed to capture the unobserved heterogeneity and cluster characteristics of observations, which seems to be the most convenient way to estimate equation (6-1). The Hausman test shows that the null hypothesis is rejected, and the results estimated by the FE model are shown in Table 6-2 Model B.

However, the results of the FE model may be misleading when the interaction terms are involved. To see how the problem arises, we simplify the production function and modify equation (6-1) with only two inputs as follows:

$$Y_{it} = \beta_0 + \beta_1 L_{it} + \beta_2 N_{it} + \beta_3 L_{it} N_{it} + v_i + u_{it}\,,\ t = 1,......,T\,,\ i = 1,......,n\,, \qquad (6\text{-}2)$$

where v_i is an additively separable, unobserved fixed effect.

The explanatory variables can be supposedly decomposed into $L_{it} = \overline{L}_i + \Delta L_{it}$ and $N_{it} = \overline{N}_i + \Delta N_{it}$, where $\overline{L}_i = T^{-1}\sum_{t=1}^{T} L_{it}$, $\overline{N}_i = T^{-1}\sum_{t=1}^{T} N_{it}$, ΔL_{it} and ΔN_{it} measure the annual deviations from the level of years. Then equation (6-2) turns to:

$$\begin{aligned} Y_{it} &= \beta_0 + \beta_1(\overline{L}_i + \Delta L_{it}) + \beta_2(\overline{N}_i + \Delta N_{it}) + \\ &\beta_3(\overline{L}_i + \Delta L_{it})(\overline{N}_i + \Delta N_{it}) + v_i + u_{it} \end{aligned}\,, \qquad (6\text{-}3)$$

while $\overline{Y}_{it}$ becomes:

$$\overline{Y}_{it} = \beta_0 + \beta_1(\overline{L}_i) + \beta_2(\overline{N}_i) + \beta_3(\overline{L_i N_i}) + \overline{v}_i + u_{it}\,. \qquad (6\text{-}4)$$

Subtracting equation (6-4) from equation (6-3), we get:

of share equations dependent on input quantities may be used to provide an estimate of this parameter, it does not solve the endogeneity problems discussed below. Furthermore, it requires the calculation of cost shares for all inputs, which in our case is prohibited by lacking data, particularly for labor and land. It is unclear how fragmentation could be included in such an approach. We therefore resort to estimating (6-1) in a direct, primal way. See MUNDLAK (2001, p. 30) for critical remarks on the dual approach to estimating production technology.

$$Y_{it} - \overline{Y}_{it} = \beta_0 + \beta_1(\overline{L}_i + \Delta L_{it} - \overline{L}_i) + \beta_2(\overline{N}_i + \Delta N_{it} - \overline{N}_i) + \beta_3(\overline{L}_i\overline{N}_i + \Delta L_{it}\overline{N}_i + \Delta N_{it}\overline{L}_i + \Delta L_{it}\Delta N_{it} - \overline{L_i N_i}) + u_{it} \quad . \quad (6\text{-}5)$$

Note that neither $\overline{L}_i\overline{N}_i$ nor $\overline{L_i N_i}$ are addictively separable in $\overline{L}_i$ and $\overline{N}_i$, and that $\overline{L}_i\overline{N}_i \neq \overline{L_i N_i}$. Therefore, equation (6-5) is not independent of levels, so that a fixed effects model does not eliminate the level effect in the presence of interaction terms. Hence, applying an FE model depends on the assumption of linear additivity of the fixed effects (ANGRIST and PISCHKE, 2009, p. 222).

To avoid the problem presented above, this thesis applies an alternative method to eliminate the fixed effect, which is a fixed effects transformation (WOOLDRIDGE, 2009, p. 481). To implement this method, we transform the observed value into time-demeaned data, so equation (6-1) turns to:

$$\ln\ddot{Y}_{it} = \beta_0 + \beta_1\ln\ddot{L}_{it} + \beta_2\ln\ddot{K}_{it} + \beta_3\ln\ddot{A}_{it} + \beta_4\ln\ddot{N}_{it} + \beta_5\ln\ddot{N}_{it}\ln L_{it} + \beta_6\ln\ddot{N}_{it}\ln\ddot{A}_{it} + \beta_7\ln\ddot{A}_{it}\ln\ddot{K}_{it} + \beta_8\ln\ddot{L}_{it}\ln\ddot{K}_{it} + \beta_9\ln\ddot{N}_{it}\ln\ddot{K}_{it} + \beta_{10}\ln\ddot{L}_{it}\ln\ddot{A}_{it} + \beta_{11}(\ln\ddot{L}_{it})^2 + \beta_{12}(\ln\ddot{K}_{it})^2 + \beta_{13}(\ln\ddot{A}_{it})^2 + \beta_{14}(\ln\ddot{N})^2 + \ddot{u}_{it} \quad , (6\text{-}6)$$

where $\ddot{Y}_{it} = Y_{it} - \overline{Y}_i$, $\ddot{L}_{it} = L_{it} - \overline{L}_i$, $\ddot{K}_{it} = K_{it} - \overline{K}_i$, $\ddot{A}_{it} = A_{it} - \overline{A}_i$, and $\ddot{N}_{it} = N_{it} - \overline{N}_i$.

The unbiased estimation will be obtained by estimating the equation above with OLS and adjusting the standard errors with respect to the real degrees of freedom (see Appendix A.2, p. 153-154, for more details).

6.4.2 Results

The regression results are shown in Tables 6-2 and 6-3. All coefficients of the three inputs of labor, land and capital in Model A and B are positive. The inputs represent the production elasticities at geometric sample means and are generally in a plausible order of magnitude. Scale elasticity, given as the sum of the partial production elasticities of the three inputs in Model B, is 0.83, which is close to the result of WAN and CHENG (2001). Hence, the mean farm operates at decreasing returns to scale, which is theoretically consistent. Labor elasticity is 0.16, and capital elasticity is 0.30 in Model B, both of which are similar to the results estimated by LIN (1992), while the land elasticity is 0.37, which is lower in our case.

As previously discussed, the FE model cannot obtain unbiased results, so an estimation of equation (6-6) with pooled OLS was employed; so the results are presented in Model C (Table 6-3). The partial elasticities in Model C are all plausible, and the effect of land fragmentation on agricultural production is not significantly different from 0 at the 10 % level. This result is consistent with the finding by WU et al. (2005). Next, we examine the effect that land fragmentation has on output and labor productivity. After controlling for the unobserved heterogeneity and clustering of households within villages, the interaction term of labor input and the number of plots turns out to be significant at the 5 % level in Model C, while it is not significant in either Model A or Model B. The reduction of capital input that results from land fragmentation is not significant in general, which may be due to less machinery usage in these three provinces.

Given the variety of agricultural production in the three provinces described in section 5.1 (p. 43-52), we may wonder whether the effect of land fragmentation on MPL changes due to the diversified production technologies in different regions, so we replace the interaction of labor input and the number of plots with the corresponding regional dummies (see Model D in Table 6-3). The results show that the effect of land fragmentation on MPL differs among provinces. Holding all the agricultural inputs constant, more plots lead to a decrease of agricultural labor productivity in Zhejiang, while they fail to decrease agricultural labor productivity significantly in Hubei and Yunnan.

One explanation for the insignificant effect of land fragmentation on labor productivity ($\beta_5 = 0$) in Hubei and Yunnan may be that the farmers apply a more labor intensive manner of cultivation in both provinces. Following this line of reasoning, the farmers can reduce the waste of labor by intensive cropping operation with respect to all the plots they have, and the negative effect of land fragmentation is eliminated by the benefits. Therefore land fragmentation does not affect labor productivity significantly. The intensive operation mode also illustrates that rural laborers still lack non-agricultural work opportunities to improve their income; thereby, labor input is over-utilized (TIAN and WAN, 2000).

However, a negative effect ($\beta_5 < 0$) is found in Zhejiang, and land fragmentation results in a decrease of labor productivity due to the high cost of land fragmentation. The increase of output due to more labor input cannot compensate for the opportunity costs of the time wasted on fragmented farms. Therefore, land fragmentation lowers labor productivity.

Table 6-2: Translog production function with OLS and FE

	Model A (OLS)		*Model B (FE)*	
Variable	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Labor	0.18	0.14	0.16**	0.06
Capital	0.35***	0.08	0.3***	0.07
Land	0.17	0.23	0.37***	0.04
Plots	-0.05	0.09	-0.01	0.04
Plots*labor	0.11	0.10	-0.05	0.05
Plots*land	-0.21	0.20	0.07	0.06
Land*capital	0.06	0.07	0.04	0.03
Capital*labor	0.07	0.07	-0.02	0.03
Plots*capital	-0.08*	0.05	-0.03	0.04
Labor*land	-0.18	0.16	0.05	0.07
Labor^2	-0.07	0.05	-0.11***	0.03
Capital^2	0.08	0.07	0.04**	0.02
Land^2	0.07	0.10	-0.01	0.04
Plots^2	0.09	0.14	-0.06	0.04
Year 1996	-0.2	0.14	-0.18	0.13
Year 1997	-0.22***	0.06	-0.21***	0.06
Year 1998	-0.3***	0.06	-0.3***	0.06
Year 1999	-0.38***	0.05	-0.38***	0.05
Year 2000	-0.5***	0.07	-0.48***	0.06
Year 2001	-0.57***	0.08	-0.55***	0.09
Year 2002	-0.78***	0.09	-0.75***	0.10
Constant	0.36	0.23	0.41***	0.04
Number of obs.	12,104		12,104	
Cluster robust standard errors	Yes		Yes	
Number of clusters	29		29	

Note: All metric variables demeaned and in logs. *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level.

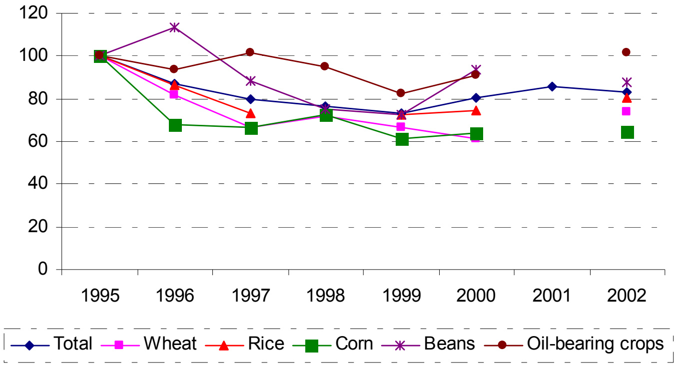
Table 6-3: Translog production function with time-demeaned OLS

	Model C (Time-demeaned OLS)		*Model D (Time-demeaned OLS)*	
Variable	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Labor	0.26***	0.08	0.26***	0.08
Capital	0.25***	0.07	0.26***	0.07
Land	0.36***	0.05	0.36***	0.05
Plots	0.08	0.05	0.08	0.05
Plots*labor	-0.15**	0.07		
Zhejiang*Plots* labor			-0.27***	0.07
Hubei*Plots* labor			-0.1	0.07
Yunnan*Plots* labor			-0.08	0.10
Plots*land	0.13	0.14	0.12	0.14
Land*capital	0.03	0.05	0.03	0.05
Capital*labor	-0.1***	0.03	-0.1***	0.03
Plots*capital	-0.08	0.07	-0.08	0.07
Labor*land	0.22**	0.11	0.22**	0.11
Labor^2	-0.03	0.05	-0.02	0.05
Capital^2	0.04**	0.02	0.04**	0.02
Land^2	-0.05	0.08	-0.05	0.08
Plots^2	0.07	0.06	0.08	0.06
Year 1996	0.13	0.13	0.13	0.13
Year 1997	0.11**	0.05	0.11**	0.05
Year 1998	0.04	0.04	0.04	0.04
Year 1999	-0.03	0.06	-0.03	0.06
Year 2000	-0.13***	0.04	-0.13***	0.04
Year 2001	-0.19***	0.07	-0.19***	0.07
Year 2002	-0.39***	0.09	-0.39***	0.09
Number of obs	12,104		12,104	
Cluster robust standard errors	Yes		Yes	
Number of clusters	29		29	

Note: All metric variables demeaned and in logs. *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level.

The results also show that the year dummies are significantly negative from 2000 to 2002, which results from the overall decrease of agricultural products during this period. In the production function, the output value is calculated according to the current price of each crop and deflation index of each year (1995=100). Therefore, controlling for all the inputs, the output value fluctuates with the change of agricultural productivity (usually associated with technology improvement over time) and agricultural price. In section 5.1, (p. 43), it is illustrated that the productivity for the main crops in three provinces did not improve notably, whereas the price of main agricultural products in the research areas experienced a large depression since 1997. So in general, the total output value at 1995 prices decreased. The price index for each product after deflating the rural consumption index is depicted in Figure 6-1. The graph shows that all agricultural product prices except for soybean experienced a significant reduction from after 1995, and it was only around 83 % of the 1995 price for total agricultural products in 2002.

Figure 6-1: Agricultural price index 1995-2002 (1995=100)



Source: CHINA STATISTICAL YEARBOOK (2001-2003).

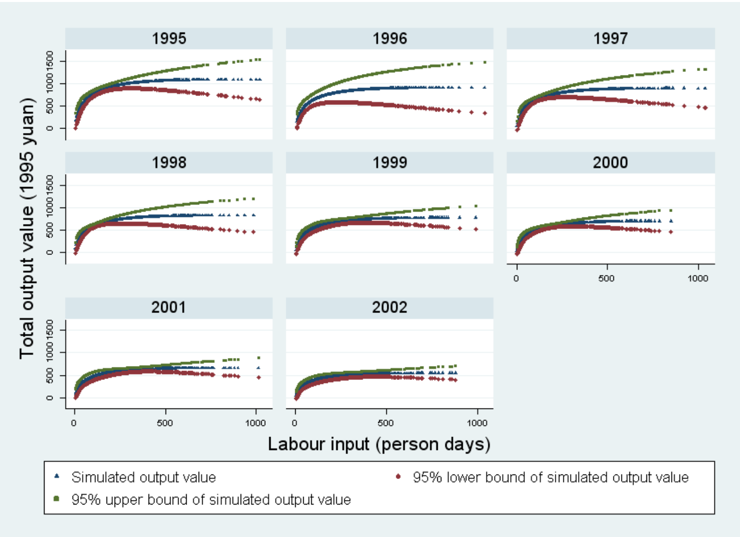
Note: The agricultural price index is the purchase price index for farm products before 2000, and the producer's price index for farm products since 2001.

Another concern in the estimations of production functions is the endogeneity of inputs (DEATON, 1995, p. 1824). As we have discussed in section 4.2 (p. 38), while variations in output may well be explained by variations in inputs on statistical grounds, the concern is that this correlation may be spurious and not due to an appropriately specified causal effect. Hence, the "independent" portion of the i.i.d. -assumption is violated. To the extent that the omitted factors are constant and their effect is additively separable, a fixed-effects approach yields unbiased estimates of the causal effect. If the variation of inputs over time is assumed to be endogenous, the fixed-effects approach will be biased and the IV method should be adopted. Capital input is regarded as exogenous in our estimation. Land and the number of plots are assumed to be exogenous and thus serve as their own instruments due to the restrictions of the Chinese land market, as described in section 2.3 (p. 20). The most potential endogenous variable here is labor input and one commonly applied strategy is to use instrumental variables. Such instrumental variables must not be a part of the production function, but should have explanatory power with regard to input levels. However, no satisfied instrumental variables can be found in our estimation and the endogeneity issue cannot be tackled in this monograph.

6.4.3 Post-estimation analysis

The output value, together with a 95 % confidence interval (CI), is simulated based on the estimation results of the Model C at the means of the other inputs, except for labor. A graph with respect to simulated output value against labor input by years is drawn in the following (Figure 6-2). The graph shows that with the increase of labor input, the total output value is growing, but at a decreasing speed for all years, while all the other inputs are controlled, which indicates the monotonicity and concavity properties of the estimated production function.

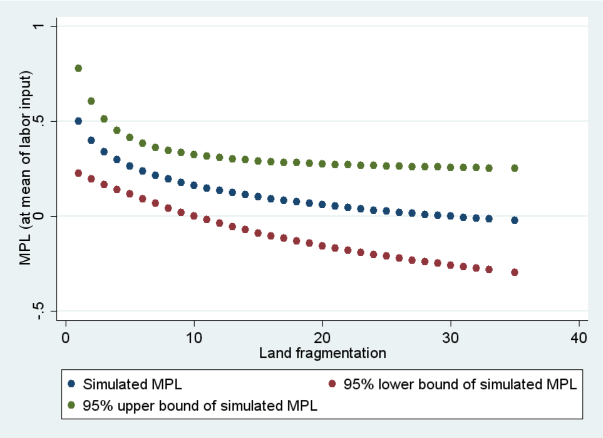
Figure 6-2: Simulated output value and labor input (1995-2002)



Source: Author's calculation.

The central concern of this section is to pinpoint the effect of land fragmentation on the MPL. Revisiting the estimation results of Model C, the MPL and its 95 % CI are calculated by adopting the delta method (DEATON, 1997, p. 128-129; GREENE, 2003, p. 913-914) for each year. The graph (Figure 6-3) presents the relationship between the MPL and land fragmentation by years. While keeping the labor input constant (at mean values to simplify the calculation), an increase of land fragmentation results in a decrease of MPL. So generally, it is consistent with Figure 3-1(c) (p. 27) in our theoretical analysis, and the land fragmentation leads to a decrease of MPL.

Figure 6-3: The effect of land fragmentation on MPL (1995-2002)



Source: Author's calculation.

6.5 Conclusions and outlook

Overall, the results in this chapter suggest a significantly negative effect of land fragmentation on labor productivity in China. These findings are robust to time-invariant heterogeneity and cluster standard errors. The effect of land fragmentation on labor productivity depends on the local shape of the production function. Following the logic of the agricultural household model outlined in section 3.1 (p. 25), political reforms that allow land consolidation hence would decrease the off-farm labor supply because of an increase of the on-farm labor input, while keeping the total working time constant. However, we also observe that the negative impact of land fragmentation on MPL is significant in Zhejiang, but not obvious in Hubei and Yunnan.

In a further step, the effect of land fragmentation on labor supply shall be tested by including a land fragmentation indicator in an off-farm labor supply equation. One issue to tackle in such an analysis is how a reduced supply equation should be formulated. Treating plots as a fixed resource, the assumption of a perfect labor market may be hard to maintain in rural China. In the presence of market imperfections, whether the effect of land fragmentation on off-farm labor supply can be observed in an incomplete labor market needs to be detected in the next chapter.

7 THE EFFECT OF LAND FRAGMENTATION ON OFF-FARM LABOR SUPPLY

The empirical study undertaken in this chapter is meant to pinpoint the effect of land fragmentation on the off-farm labor supply by obtaining a robust estimate of an off-farm labor supply function. In light of the theoretical framework presented in section 3.2 (p. 28), some sequential econometrical challenges arise; this section will explicitly target the consistent estimate of the off-farm labor supply function with panel data in the presence of endogeneity, time-invariant heterogeneity, and the selection and clustering of observations.

In the following chapter, section 7.1 presents an overview of the literature with respect to off-farm labor supply. section 7.2 discusses the empirical strategies that will be employed in the estimation. section 7.3 describes the database, and section 7.4 elaborates the results. section 7.5 draws conclusions.

7.1 An overview of off-farm labor supply estimations

In the literature, four main approaches are used to estimate the determinants of the off-farm labor supply and a generalization of methodologies based on former studies (see Table 7-1 and Table 7-2). The first is a bivariate model, including bivariate probit and logit; the second is a multinomial logit model; the third is a hazard model; the fourth is to estimate the amount of the off-farm labor supply with multiple regressions.

GOULD and SAUPE (1989) estimated the determinants of the off-farm labor market entry and exit for married farm women in the U.S. by using a panel probit model, and the off-farm wage was instrumented due to the endogeneity of structural switching. A similar bivariate probit model is also applied in the studies of the factors that influence off-farm work participation and return migration in Slovenia and China (ZHAO, 2002; JUVANCIC and ERJAVEC, 2005; WANG et al., 2007). However, no studies have considered the unobserved heterogeneity in sample selection of the probit model.

DE BRAUW et al. (2002) used a fixed effects conditional logit model to control the unobserved time-invariant endogeneity in the study of the off-farm employment evolution in rural China over twenty years, and indicated that people who were older, had better human capital, and were male, had more incentives to migrate and also increased the probability of working off-farm for the individual's family members. The importance of human capital is also supported by UCHIDA et al. (2009), who adopted the Difference In Difference (DID) probit approach to measure the policy impacts of the Grain-for-Green project on the off-farm labor supply, and argued that this project increased the possibility to shift from on-farm to off-farm employment for those farmers having a better initial level of human and physical capital.

Some other studies focus on the multiple choices of off-farm participation. KIMHI (2000) adopted a multinomial logit model by allowing farmers to vary among part-time off-farm work, full-time off-farm work and no off-farm work, and found that Israeli family farmers chose off-farm work only when they had stable on-farm work in the long-run; this was due to an entire life-cycle of decision-making. CHEN et al. (2004) explored the off-farm choices made by farmers by controlling the panel data sample selection bias in a multinomial logit model with WOOLDRIDGE's (2005) approach, and found that rural households with more laborers and better education were inclined to have more off-farm opportunities.

A dynamic labor market participation model was estimated by BROSIG et al. (2007) and BROSIG et al. (2009) with a hazard approach in order to map the possibilities of changing an occupational state for households in China. The results reveal that participation in any labor market and off-farm employment is more or less stable, the risks of entering are higher, and of leaving are lower (BROSIG et al., 2007). The full-time farming households are trapped and lack opportunities to move to part-time farming in southern China (BROSIG et al., 2009).

In the framework of a microeconomic household model, an off-farm labor supply function can be estimated directly in terms of the off-farm wage, and all variables affecting the marginal value of time both on farming and non-work activities (SUMNER, 1982). As carried out by SUMNER (1982) and WANG et al. (2007), an instrumental methodology was employed to tackle the endogeneity of the off-farm wage, and HECKMAN's method (1979) was employed to deal with the sample selection bias. The results show that the accumulation of productive assets, the development of livestock production and agricultural prices promote labor demand, but reduce off-farm labor supply (WANG et al., 2007). However, Heckman's method in an FE model is inconsistent if the sample selection bias is not constant through the years, and the distribution of residuals possibly is mis-specified (KYRIAZIDOU, 1997). Below, we motivate the approach to estimate the off-farm labor supply function and obtain the results robust to endogeneity, time-invariant heterogeneity, clustering of observations and sample selection bias.

Table 7-1: An overview of off-farm labor supply estimations (1)

Author	*Data properties*	*Method*	*Sample selection bias*	*Dependent variable*	*Main independent variables*
GOULD and SAUPE (1989)	Panel	Probit model	Heckit	Participation of off-farm work	Wage, age, training, etc.
JUVANCIC and ERJAVEC (2005)	Cross-section	Probit	Meng and Schmidt's approach (1985)	Off-farm employment	Off-farm income, farm size, education, age, etc.
ZHAO (2002)	Cross-section	Bivariate logit	No check	Return migration	Male, married, age, education, etc.
DE BRAUW et al. (2002)	Twenty-year panel	Fixed effects conditional logit	No check	Migration; local wage employment; self-employment	Age, gender, years of education, skill, land area, etc.
UCHIDA et al. (2009)	Panel	DID Probit	No check	Participation of off-farm work	Age, education, etc.

Source: Author's compilation.

Table 7-2: An overview of off-farm labor supply estimations (2)

Author	*Data properties*	*Method*	*Sample selection bias*	*Dependent variable*	*Main independent variables*
CHEN et al. (2004)	Five-year Panel	Bivariate and multinonimal logit	Wooldridge method	Off-farm work; full-time farming, local off-farm a ctivities, migration	State dependence, household size, etc.
KIMHI (2000)	Two-year panel	Multinomial logit	No check	Part-time off-farm work, full-time off-farm work, and no off-farm work	Age, number of family mem-bers, number of off-farm members, land, capital, etc.
BROSIG et al. (2007)	Eight-year panel	Hazard model	No check	Autarky to participation; participation to autarky; full-time to part-time; part-time to full-times	Duration years; household size; farm size; education; land market, etc.
SUMNER (1982)	Cross-section	Off-farm labor supply function	Heckit	Participation in off-farm work; hours of off-farm	Wage, education, age, farming experience, etc.
WANG et al. (2007)	Eight-year panel	Off-farm labor supply and on-farm labor de-mand function	Heckit	Off-farm employment; off-farm working days	Hired wage, off-farm wage, education level, male and female laborers. etc.

Source: Author's compilation.

7.2 Empirical strategy

7.2.1 Functional form

Following the theoretical framework in section 3.2 (p. 28), the off-farm labor supply is a projection of off-farm wage and other demographic variables that can be specified as follows:

$$L_{it}^{o} = \delta_0 + \delta_1 w_{it} + \delta_2 x_{it} + v_i + u_{it}, \qquad t = 1,......,T,\ i = 1,......,n, \qquad (7\text{-}1)$$

where x_{it} includes all the other independent variables except for the off-farm wage w_{it}, such as the number of plots as a measure of land fragmentation degree and the demographic characteristics, δ_0, δ_1, δ_2 are unknown parameter vectors, v_i is the unobserved time-invariant effects, and u_{it} is the idiosyncratic errors.

7.2.2 Endogeneity

As discussed above (see section 3.2, p. 28), the labor market in rural China is imperfect and the off-farm wage is not exogenous to the off-farm labor supply. Therefore, the instrumental variables should be employed as shown in the following equation:

$$w_{it} = \phi_0 + \phi z_{it} + c_i + \upsilon_{it}, \qquad (7\text{-}2)$$

where z_{it} indicates instrumental variables of the off-farm wage, c_i is the unobserved time-invariant effects, υ_{it} is the idiosyncratic errors, and ϕ_0 and ϕ are unknown parameter vectors.

As mentioned in section 4.1 (p. 37), a joint estimation of equation (7-1) and (7-2) with the FE-2SLS model is robust when v_i is time-invariant and the idiosyncratic errors u_{it} are independent of z_{it} and v_i, which means $E(u_{it} \mid z_{it}, v_i) = 0$ and $E(\upsilon_{it} \mid z_{it}, c_i) = 0$. However, when the sample selection bias is not systematic across the years, u_{it} will be correlated with the sample selection condition s_{it}, then $E(u_{it} \mid z_{it}, v_i) \neq 0$ and $E(\upsilon_{it} \mid z_{it}, c_i) \neq 0$. Hence the robustness of FE-2SLS may be violated due to the incidental truncation of the off-farm labor participation, which gives rise to the problem of sample selection bias. So a test for the sample selection bias is indispensable.

7.2.3 Panel data sample selection model

In the estimation of the off-farm labor supply function, the sample selection bias is often given special attention due to the common incidental truncation problem (GREENE, 2003, p. 782; WOOLDRIDGE, 2002, p. 552). This problem is particularly relevant when panel data are used, because neither the FE-2SLS approach nor HECKMAN's approach (1979) provides consistent estimates. The selection bias probably is not constant across the time period, thus leading to a violation of the FE-2SLS model in terms of the independent part of the i.i.d assumption when the time period is not short (WOOLDRIDGE, 2002, p. 580). This leads to an exploration of econometrical methodologies to address the sample selection bias and the time-invariant effects concurrently.

There are three methods used to estimate a panel data sample selection model, and the main properties of each are presented in Table 7-3. WOOLDRIDGE (1995) developed the level equations to obtain consistent estimations with a pooled 2SLS method by parameterizing the conditional expectations. This method is available for unbalanced panel data and can test both the time heteroskedasticity and the serial correlation. KYRIAZIDOU (1997) treated a sample selection functional form as unknown and employed the first difference to estimate the main function. This method requires balanced panel data. In addition, it imposes one restrictive assumption; that the sample selection effect is equal for individuals z_{it} and z_{iu} in t and u in terms of the selected samples, which is unlikely to hold when the distribution changes over time (DUSTMANN and ROCHINA-BARRACHINA, 2007). ROCHINA-BARRACHINA (1999) formulated another approach with respect to the estimation in differences which parameterized the sample selection effects but did not require the strong assumption of conditional exchangeability.

After comparing the three methods, we will adopt WOOLDRIDGE's (1995) methodology due to its ability to test the time-invariant heteroskedasticity and the sample selection effects, and no requirements for balanced panel data.

Table 7-3: Comparison of estimators

Estimators	*Estimation*	*Sample selection effects*	*Time Heterok.*	*Serial correction*	*Sample requirements*
Wooldridge	Levels	Parameterized	Yes	Yes	$s_{it} = 1$
Kyriazidou	Time diff.	Unspecified	No	Conditional exchangeability	$s_{it} = s_{iu} = 1$ $z_{it}\gamma \cong z_{iu}\gamma$
Rochina-Barrachina	Time diff.	Parameterized	Yes	Yes	$s_{it} = s_{iu} = 1$

Source: Adapted from DUSTMANN and ROCHINA-BARRACHINA (2007). $s_{it} = 1$ means the concerned observation is selected.

According to WOOLDRIDGE (1995; 2002, p. 582), the labor supply function in consideration of sample selection bias for panel data is estimated in the following equation:

$$L_{it1}^{o} = \delta_0 + \delta_1 w_{it1} + \delta_2 x_{it1} + \psi_1 \overline{x_{i1}} + \ell_t \lambda(H_{it2}) + u_{it1}, \qquad (7\text{-}3)$$

where $\lambda(\cdot)$ are the inverse Mills ratios (IMR) calculated according to H_{it2}, which is a reduced index for the selection equation and determined by the probit model:

$$s_{it} = 1[v_{i2} + \varphi_{t2} x_{it2} + \varepsilon_{it2} > 0], \qquad \varepsilon_{it2} \mid x_i \sim \text{Normal}(0,1), \qquad (7\text{-}4)$$

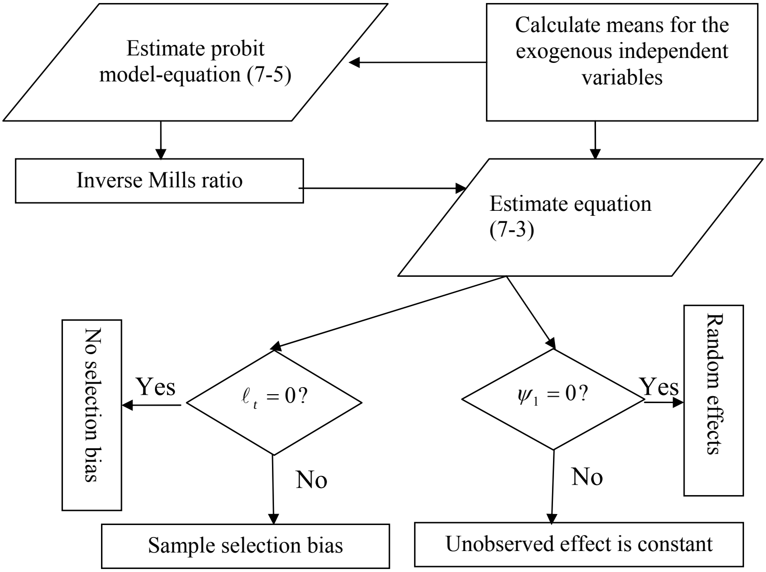
δ_0, δ_1, δ_2, ψ_1, φ_{t2} and ℓ_t are unknown parameter vectors, and ε_{it2} is an idiosyncratic error. Two methodologies are used to estimate H_{it2} in the literature: one is a dynamic model proposed by CHAMBERLAIN (1980), and another is MUNDLAK's (1978) approach, which has the advantage of conserving the degrees of freedom (WOOLDRIDGE, 2002, p. 582). For this reason, we adopt MUNDLAK'S (1978) approach and replace v_{i2} with $\eta_2 + \bar{x}_{i2}$, thus the probit model becomes:

$$s_{it} = 1[\eta_2 + \gamma_{t2} x_{it2} + \xi_{t2} \bar{x}_{i2} + \varepsilon_{it2} > 0], \qquad \varepsilon_{it2} \mid x_i \sim \text{Normal}(0,1), \qquad (7\text{-}5)$$

where η_2, γ_{t2} and ξ_{t2} are unknown parameter vectors, x_{it2} contains all the exogenous variables which are the exogenous in equation (11) and instrumental variables for w_{it1}, and $\bar{x}_{i2}$ is the means of all these exogenous variables.

The procedures used to estimate the panel data sample selection model are revealed in Figure 7-1. First we calculate the means for each exogenous independent variable $\bar{x}_{i2}$. Then we estimate the probit model in equation (7-5) for each year. Based on the results of the probit model, we estimate IMR $\lambda(\cdot)$ and insert them into the panel data sample selection model. A test for sample selection bias based on an estimation of equation (7-3) is conducted with a pooled 2SLS model, and a joint rejection of ℓ coefficients indicates the existence of sample selection bias, while a joint rejection of ψ coefficients can be interpreted as a correlation of individual effects (SEMYKINA and WOOLDRIDGE, 2010; DUSTMANN and ROCHINA-BARRACHINA, 2007).

Figure 7-1: Estimating procedures for the panel data sample selection model



Source: Author's presentation.

7.3 Data description

The whole data set contains the households who both participate in the off-farm work and those do not. But we can only use those household samples involved in the off-farm work of specific years in our estimation since the off-farm wage is only observable in this case. Two groups of datasets are distinguished: the overall population is the whole dataset including all observations, while the subpopulation refers to the selected observations. The mean value and standard deviation of variables for both overall population and off-farm population in three provinces are reported in Table 7-4. There are 10,207 observations in three provinces from 1995-2002 in our database, but only 7,302 observations participated in off-farm work. Each overall population household, on average, provides 249 person days every year, while the subpopulation delivers 326 person days every year. The average off-farm wage is 22 yuan/day for the overall population and 30 yuan/day for the subpopulation. Generally, the overall population has a greater number of plots, 6.51 on average, than the subpopulation, at 5.91. The average amount of land per capita is smaller, while the average net income per capita in the village and the number of out-migrants in the village are higher for the subpopulation than for the overall population. The indicators of the other variables are similar for both overall population and subpopulation, though the average educational levels are slightly higher and the number of unemployed people in the village is slightly smaller for the subpopulation.

Table 7-4: Data description

Variables	*Overall population*		*Off-farm population*	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
Off-farm labor input (per person days)	248.95	278.13	325.95	244.18
Off-farm wage (yuan/day)	21.99	42.06	30.05	47.02
Pesticide price (yuan/kilogram)	15.48	10.63	15.31	9.48
Distance of village to main concrete road[a] (km)	1.55	3.26	1.61	3.31
Percentage of total arable land participating in village land market[a]	0.07	0.13	0.08	0.14
Number of plots	6.51	4.78	5.91	4.26
Number of members in the household	4.07	1.44	4.19	1.38
Average land per capita (mu) [a]	1.21	0.95	1.08	0.80
Number of members having elementary education level in the household	1.06	0.92	1.09	0.90
Number of members having secondary school level in the household	0.94	0.92	1.03	0.94
Number of members having high school level in the household	0.16	0.43	0.17	0.45
Average net income per capita in the village[a]	2521.59	1947.88	2781.23	2090.97
Number of observations	10,828		7,317	

Note: [a] Indicates the variable of village level.

7.4 The effect of land fragmentation on off-farm labor supply

7.4.1 Test for sample selection bias in panel data model

Following the methodology of WOOLDRIDGE (2002, p. 581-585), this section will test the existence of sample selection bias. If the null hypothesis, that there is no sample selection bias, cannot be rejected, FE-2SLS is still efficient for estimating the off-farm supply function. Otherwise, a correction of sample selection bias with panel data model should be adopted. Here, we avoid estimating the off-farm wage first and inserting the prediction of off-farm wage into the off-farm labor supply function, as done by SUMNER (1982) and WANG et al. (2007). This method presumes that the composition term $c_i + \upsilon_{it}$ in equation (7-2) is a linear projection on ε_{it2} in the structural model, which is likely not true (WOOLDRIDGE, 2005, p. 23). Thus, we assume that $E(c_i \mid \varepsilon_{it}) = \rho$, but not $E(c_i + \upsilon_{it} \mid \varepsilon_{it}) = \rho$.

7.4.2 Results

The results of the FE-2SLS model without considering the sample selection bias are presented as Model E in Table 7-5. The excluded instrumental variables in Model E are the log of pesticide prices, the distance of the village to the main concrete road, and the average net income per capita in the village. The results of Model E show that the off-farm wage increases the amount of off-farm labor supply once the instrumental variables are introduced, but the land fragmentation degree has no significant effect on the off-farm labor supply of households. The household size and all education levels have positive contributions to an increase of the off-farm labor supply in the FE-2SLS, while the land endowment has a negative impact on off-farm labor supply model. This result is robust to endogeneity, time-invariant heterogeneity and the clustering characteristics of samples, but not to the sample selection bias.

To control the sample selection, we estimated equation (7-3) with pooled 2SLS, and the results are reported as Model F in Table 7-5. The tests for the panel data sample selection bias and the fixed effects were obtained by employing joint Wald tests. The results reveal that the Wald test statistical value for sample selection is χ_8^2=36.79, implying a rejection of the null hypothesis ($\ell_1 = \ell_2 ...... = \ell_8 = 0$), that there is sample selection bias at the 1 % significance level. Therefore, the approach of controlling sample selection bias in panel data is demanded in estimating off-farm labor supply. The Wald test statistic for testing for fixed effects is χ_7^2=50.78, indicating the null hypothesis of the joint significance of ψ coefficients ($H_O : \psi_1 = \psi_2 ...... = \psi_7 = 0$) is rejected at the 1 % significance level. In this way, the Model F is robust to sample selection bias and allows the correlation between the unobserved effect and independent variables.

The results of Model F show that land fragmentation tends to have positive impacts on the off-farm labor supply but that they are not significant. Thus, the land consolidation has a neutral effect on off-farm labor supply. An increase of the off-farm wage significantly leads to an increase of the off-farm labor supply, which is consistent with previous studies (WANG et al., 2007; SUMNER, 1982). The households with greater land endowments supply less off-farm labor, which is significant at the 5 % level. However, the number of members in the household has no significant impact on the off-farm labor supply after controlling for sample selection bias. The educational levels contribute to an increase of the off-farm labor supply, implying that the households with less land and better education supply more off-farm labor. These findings are also consistent with the outcomes of previous studies (DE BRAUW et al., 2002; WANG et al., 2007; UCHIDA et al., 2009). The development of the land market has no significant impact on off-farm labor supply.

The over-identification test shows that the instrumental variables are valid in both Model E and Model F. However, we may wonder whether the effect of the degree of land fragmentation on off-farm labor supply is influenced by the instrumental variables. An alternative way to deal with the endogeneity problem in the off-farm labor supply function is to replace the individual off-farm wage with the provincial average off-farm wage for each year and estimate the off-farm labor supply function. The results show that the number of plots is still not significant at the 10 % level (see Table 7-7). Thereby, the neutral effect of land fragmentation on off-farm labor supply is confirmed.

Table 7-5: Estimation results of off-farm labor supply

	Model E (FE-2SLS)		*Model F (Panel data sample selection model)*	
Variables	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Log of off-farm wage	0.18	0.16	0.64***	0.24
Log of plots	0.02	0.07	0.13	0.09
Percentage of total arable land participating in the village land market[a]	0.07	0.16	-0.01	0.26
Number of members in the household	0.04**	0.02	0.02	0.02
Log of average land per capita	-0.09*	0.05	-0.14**	0.07
Number of members having elementary education level in the household	0.10***	0.03	0.11***	0.04
Number of members having secondary school level in the household	0.24***	0.04	0.23***	0.04
Number of members having high school level in the household	0.25***	0.04	0.21***	0.05
F	F(8, 28) = 17.44		F(8, 28) = 8.24	
Over-identification test	0.64		0.18	
Number of observations	7,302		7,302	
Cluster robust standard errors	Yes		Yes	
Number of clusters	29		29	
Sample selection	No		Yes	
Fixed effects controlled by	Differencing out group average		Mundlak's approach	

Note: [a] Indicates the variable of the village level, *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level. The dependent variable is the log of the off-farm labor supply. Sample selection bias test for Model F: χ_8^2=36.79(0.01). Fixed effects test for Model F: χ_7^2=50.78(0.00).

The first stage results of the off-farm supply function with respect to the off-farm wage regression of models E and F are shown in Table 7-6. The average net income per capita in the village is significantly beneficial for promoting the off-farm wage of households in both regressions. All education levels do not significantly influence off-farm wage, which may be due to the poorly developed labor market, where some other factors such as one's social network play an important role in getting more off-farm opportunities and higher payment.

The number of plots has a negative impact on off-farm wage, but is only significant in the first stage regression of Model E. The distance of village to main concrete road reduces the off-farm wage and the average net income per capita in the village increases off-farm wage, which are significant and in plausible signs in both models.

The probit sample selection models for estimating IMR are presented in Table 7-8, Table 7-9, Table 7-10 and Table 7-11. The results indicate that the sample selection is not constant throughout the years. The degree of land fragmentation for all provinces are positively correlated with sample selection in 1997, 1999 and 2000; the average net income per capita in the village has a positive impact on sample selection in 1995, 1999, 2000 and 2002; land endowment has a significantly negative relationship with sample selection in 1996, 1997, 1999, 2000 and 2002; the educational level of the household only affects sample selection in 1997, 2000, 2001 and 2002.

In addition, we also insert regional dummies in the off-farm labor supply model to capture regional differences. However, estimation results with respect to the panel data sample selection model show that no land fragmentation in these regions has a significant impact on off-farm labor supply. This result reconfirms our hypothesis that land fragmentation may have a neutral effect on off-farm employment due to the constrained labor market. To avoid repetition, we do not present the results here.

Table 7-6: First stage regression results for off-farm wage

	For Model E		*For Model F*	
Variables	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	-0.08**	0.04	-0.06	0.03
Percentage of total arable land participating in the village land market[a]	0.14	0.21	0.21	0.19
Number of members in the household	3.36E-3	0.01	0.02	0.01
Log of average land per capita	-0.02	0.03	0.01	0.04
Number of members having elementary education level in the household	0.01	0.02	-0.02	0.02
Number of members having secondary school level in the household	-0.01	0.03	-0.05	0.03
Number of members having high school level in the household	-0.02	0.03	-0.03	0.04
Log of pesticide price (yuan)	-0.02	0.02	-0.02	0.03
Distance of village to main concrete road[a] (km)	-0.02***	3.2E-3	-0.02***	0.01
Average net income per capita in the village[a]	9.05E-5***	2.93E-05	7.5E-5***	2.8E-5
F (P-value)	F(10,28) = 5.96 (0.00)		F(13,28) = 9.71 (0.00)	
Partial R^2 of excluded instruments	0.02		0.06	
Number of observations	7,302		7,302	
Cluster robust standard errors	Yes		Yes	
Number of clusters	29		29	

Note: [a] Indicates the variable of village level, *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level. The means of excluded instrumental variables for off-farm wage are included in the estimation but not presented in the table.

Table 7-7: Estimation results of off-farm labor supply without instrumental variables

	Panel data sample selection model without instrumental variables	
Variables	*Coef.*	*Std. Err.*
Log of off-farm wage	0.16	0.25
Log of plots	0.03	0.06
Percentage of total arable land participating in the village land market[a]	0.15	0.14
Number of members in the household	0.02	0.02
Log of average land per capita	-0.09	0.06
Number of members having elementary education level in the household	0.07*	0.03
Number of members having secondary school level in the household	0.16***	0.03
Number of members having high school level in the household	0.16***	0.04
Constant	6.22***	0.98
F	F(25, 28) = 103.79	
Number of observations	7,302	
Cluster robust standard errors	Yes	
Number of clusters	29	
Sample selection	Yes	
Fixed effects controlled by	Mundlak's approach	

Note: [a] Indicates the variable of the village level, *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level. The dependent variable is the log of the off-farm labor supply. Sample selection bias test for Model F: F(8,28) =5.49(0.00). Fixed effects test for Model F: F(9,28) =3.09(0.01).

Table 7-8: Estimation results of probit model (1)

Variables	*1995 (1)*		*1996(2)*	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	0.03	0.14	0.25	0.16
Percentage of total arable land participating in the village land market[a]	0.04	0.55	-0.01	0.59
Log of pesticide price	0.09	0.07	0.06	0.07
Average net income per capita in the village [a]	1.3E-04***	4.3E-05	5.4E-05	4.3E-05
Number of unemployed people in the village [a]	1.5E-03**	6.0E-04	2.9E-03***	6.0E-04
Number of members in the household	-0.01	0.06	-0.13*	0.07
Log of average land per capita	-0.23	0.15	-0.56***	0.17
Number of outmigrants in the village[a]	-2.3E-04	2.8E-04	-3.6E-04	3.7E-04
Distance of village to main concrete road [a] (km)	0.06***	0.01	-0.03***	0.01
Number of members having elementary education level in the household	-0.03	0.08	0.04	0.09
Number of members having secondary school level in the household	0.03	0.08	0.04	0.09
Number of members having high school level in the household	0.01	0.16	0.01	0.17
Constant	-0.27	0.26	0.36	0.27
Unobserved fixed effects	Yes		Yes	
χ^2_{19} (p-value)	201.20(0.00)		210.79(0.00)	
Number of observations	1,393		1416	

Note: [a] Indicates the variable of village level, *** indicates a 1 % significance level, ** indicates a 5 % significance level, and * indicates a 10 % significance level.

Table 7-9: Estimation results of probit model (2)

Variables	*1997 (3)*		*1998 (4)*	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	0.48***	0.18	3.6E-03	0.17
Percentage of total arable land participating land market in the village[a]	-0.53	0.79	0.54	0.85
Log of pesticide price	-0.11	0.08	0.15***	0.06
Average net income per capita in the village [a]	2.6E-05	3.7E-05	-3.2E-05	3.7E-05
Number of unemployed people in the village[a]	4.1E-03***	6.7E-04	2.4E-03***	4.7E-04
Number of members in the household	-0.18**	0.08	0.04	0.08
Log of average land per capita	-0.47**	0.19	0.09	0.18
Number of outmigrants in the village[a]	1.1E-03***	3.3E-04	1.3E-03***	2.8E-04
Distance of village to main concrete road [a] (km)	0.07***	0.02	-0.02*	0.01
Number of members having elementary education level in the household	0.41***	0.10	0.04	0.10
Number of members having secondary school level in the household	0.29***	0.10	0.05	0.10
Number of members having high school level in the household	0.04	0.17	0.09	0.18
Constant	0.15	0.28	-0.10	0.24
Unobserved fixed effects	Yes		Yes	
χ^2_{19} (p-value)	287.42(0.00)		207.78(0.00)	
Number of observations	1373		1322	

Note: [a] Indicates the variable of village level, *** indicates 1 % significance level, ** indicates 5 % significance level and * indicates 10 % significance level.

Table 7-10: Estimation results of probit model (3)

Variables	*1999 (5)*		*2000 (6)*	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	0.72***	0.17	0.48***	0.18
Percentage of total arable land participating land market in the village [a]	2.34***	0.75	-0.14	0.67
Log of pesticide price	-0.02	0.07	-0.04	0.07
Average net income per capita in the village[a]	1.6E-04***	3.7E-05	6.3E-05*	3.7E-05
Number of unemployed people in the village[a]	1.8E-03***	5.1E-04	1.5E-03***	5.8E-04
Number of members in the household	-0.06	0.07	0.04	0.08
Log of average land per capita	-0.84***	0.13	-0.56***	0.18
Number of outmigrants in the village[a]	1.1E-03***	2.9E-04	1.1E-03***	2.8E-04
Distance of village to main concrete road[a] (km)	-0.08**	0.03	0.02	0.03
Number of members having elementary education level in the household	-0.06	0.11	-0.04	0.10
Number of members having secondary school level in the household	-0.05	0.11	0.21**	0.10
Number of members having high school level in the household	0.01	0.18	0.08	0.19
Constant	-0.36	0.26	0.15	0.26
Unobserved fixed effects	Yes		Yes	
χ^2_{19} (p-value)	273.86(0.00)		200.86(0.00)	
Number of observations	1405		1355	

Note: [a] Indicates the variable of village level, *** indicates 1 % significance level, ** indicates 5 % significance level and * indicates 10 % significance level.

Table 7-11: Estimation results of probit model (4)

Variables	*2001 (7)*		*2002 (8)*	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	0.05	0.18	0.16	0.16
Percentage of total arable land participating land market in the village[a]	0.54	0.91	-1.47**	0.68
Log of pesticide price	-0.13**	0.06	-0.08	0.06
Average net income per capita in the village[a]	5.2E-05	3.2E-05	9.5E-05***	3.5E-05
Number of unemployed people in the village[a]	1.9E-04	1.3E-04	1.6E-03***	5.5E-04
Number of members in the household	0.06	0.07	0.02	0.06
Log of average land per capita	-0.29	0.19	-0.47***	0.16
Number of outmigrants in the village[a]	1.0E-03***	2.9E-04	1.0E-03***	3.0E-04
Distance of village to main concrete road[a] (km)	0.01	0.03	0.04y	0.02
Number of members having elementary education level in the household	0.19**	0.09	0.13y	0.07
Number of members having secondary school level in the household	0.24***	0.08	0.24***	0.07
Number of members having high school level in the household	0.35*	0.18	0.42***	0.16
Constant	0.26	0.23	-0.16	0.28
Unobserved fixed effects	Yes		Yes	
χ^2_{19} (p-value)	244.14(0.00)		244.77(0.00)	
Number of observations	1290		1274	

Note [a] Indicates the variable of village level, *** indicates 1 % significance level, ** indicates 5 % significance level and * indicates 10 % significance level.

7.5 Conclusions

This chapter empirically estimates the off-farm labor supply function with a panel data sample selection model. The results show that land consolidation fails to affect the off-farm labor supply. These results are robust to endogeneity, time-invariant heterogeneity, sample selection bias and clustering of observations.

The finding indicates that land consolidation cannot influence the off-farm labor supply, although it may increase agricultural labor productivity. The neutral effect of land consolidation on off-farm labor supply may be due to the underdeveloped rural labor market in China, and that rural laborers lack of off-farm opportunities (see section 3.2, p. 28). How to interpret our findings? More discussion in terms of rural policy reform is presented in the next chapter.

8 DISCUSSION

Our monograph investigates the driving forces of land fragmentation in China and estimates the effects of land fragmentation on agricultural labor productivity and off-farm labor supply. We find that the current land fragmentation in China comes from an institutional demand for land decentralization, but this institution is constrained by incomplete property rights, which may lead to high transaction costs for farmers to reduce the degree of land fragmentation freely through the land market. This monograph also measures the effects of land fragmentation and the results reveal that land fragmentation may alleviate agricultural labor productivity in Zhejiang, but not in Hubei and Yunnan. Nevertheless, land fragmentation does not significantly affect the off-farm labor supply.

The critical issue for policy-makers regarding rural transformation is what kind of land reform policy should be adopted in China. This chapter will discuss the possible effects of land consolidation based on our findings and obtain more insights in the heated discussion of land reform policies in order to provide full understanding for policy-makers. The chapter is divided as follows. First, we revisit the results of chapter 2, and discuss the policy implications concerning the driving forces of Chinese land fragmentation in section 8.1; we aim to show the effects of land fragmentation in section 8.2; we then discuss whether land consolidation should be adopted in section 8.3; we examine the topic of whether a liberal land market should be adopted in section 8.4; and we conclude in section 8.5.

8.1 Supply-driven versus demand-driven institutional innovation

Following the theory of HAYAMI and RUTTAN (1985, p. 93-110), institutional change is endogenous rather than exogenous, which could be driven either by supply side or demand side forces (FEENY, 1993, p. 159-99; HAYAMI and RUTTAN, 1985, p. 93-110). This monograph analyzes the root of land fragmentation and finds that land fragmentation in China is embedded in the demand side of institutional change, but constrained by incomplete property rights. So we argue that land fragmentation in China does not solely come from either demand side or supply side driving forces, but rather from *quasi-demand* driving forces.

TAN et al. (2006) posited that the current land fragmentation in China came from the egalitarianism and land reallocation of HRS, implying supply-side driving forces. However, it was evidenced that HRS was a bottom-up institutional innovation (LIN, 1988) and land fragmentation could benefit subsistence farmers by crop diversification and capital input reduction (TAN et al., 2008; WU et al., 2005). In this sense, it is not sufficient to argue that land fragmentation in China comes from an institutional supply. Our research in China just supplements the two land-fragmentation-driving forces proposed by BLAREL et al. (1992).

As with the development of the labor market, the degree of land fragmentation is influenced by incomplete land property rights. Lacking land property rights in rural China, the land market is largely depressed. When land reallocation cannot adjust either land and labor resources efficiently (BRANDT et al., 2004), involuntary land fragmentation emerges with the increase of off-farm opportunities. Therefore, the land market, which can adjust land and labor resources more quickly and efficiently, should be developed. DEININGER and FEDER (1998) have shown that the encumbered land market did not constrain farmers since there was little heterogeneity of agricultural skills, and non-agricultural opportunities were inaccessible to most of the population, but the land exchanges might be of importance with the development of the rural economy and geographical integration.

This analysis implicitly suggests how the land market affects the degree of land fragmentation, which may depend on the development of the labor market. In the absence of off-farm opportunities, land reallocation may not increase the degree of land fragmentation, whereas with the development of the labor market, the land institution may lead to an increase of involuntary land fragmentation. This indicates that land reform targeting land consolidation should fully consider the development of the local labor market.

A *quasi-demand* side of driving forces of land fragmentation in China implies that the effects of land fragmentation may not always be positive or negative and may also be correlated with the development of local factor markets, which will be illustrated in the next section.

8.2 Positive versus negative effect

Many previous studies proposed that land fragmentation led to an efficiency and productivity loss in agricultural production (WAN and CHENG, 2001; NGUYEN et al., 1996; FLEISHER and LIU, 1992). However, the effect of land fragmentation on agricultural labor productivity has been neglected, as the effect of land fragmentation on agricultural labor productivity is significantly negative, while the effect of land fragmentation on total output is not obvious in our estimation (section 6.4.2, p. 68). In the trend of globalization and industrialization, one of the most important tasks for rural economic development is how to promote agricultural labor productivity (JIN and DEININGER, 2009), while land consolidation in this sense may contribute to it.

A further result reveals that the effect of land fragmentation on MPL varies across different regions. For example, the negative effect is significant in Zhejiang, but not in Hubei and Yunnan, where agricultural production is more labor-intensive (section 6.4.2, p. 68). When the labor market is underdeveloped, labor productivity is still low due to a lack of off-farm opportunities, and the cost of land fragmentation is not obvious. While the labor market is better developed, rural laborers have more opportunities to participate in off-farm work, which increases the opportunity cost of labor and the waste of labor due to land fragmentation becomes costly. This means that the development of the local labor market affects the marginal cost of land fragmentation.

Our findings provide a more complete view of the effect of land fragmentation on agricultural production and illustrate that the effect of land fragmentation on agricultural labor productivity can be either negative or neutral. We argue that the cost of land fragmentation is not always negative and it could be not significant in the presence of a high degree of labor surplus. In this case, the land consolidation policy may not benefit all farmers, and whether land consolidation should be adopted or not will be discussed in the subsequent section.

8.3 Land consolidation versus land fragmentation

To increase agricultural productivity, many agricultural economists have proposed that land consolidation should be implemented in China (WAN and CHENG, 2001; NGUYEN et al., 1996; FLEISHER and LIU, 1992). This monograph addresses the potential outcome of land consolidation on off-farm labor supply. Our results show that land consolidation may lead to an increase of agricultural productivity. However, this effect does not apply uniformly from the east to the west of China. Indeed, land consolidation may increase agricultural labor productivity in the region where the marginal cost of land fragmentation is high and agricultural production is less labor intensive like Zhejiang, but it is not the case for Hubei and Yunnan, where farmers overuse labor in the agricultural sector.

One plausible explanation is that farmers in less developed regions may be trapped in a labor intensive method of cultivation. These farmers would like to put forth any amount of effort to obtain more output, which leads to the inefficient use of their labor and a low marginal value of their time (BENJAMIN and BRANDT, 2002). In this sense, the cost of land fragmentation is compensated by intensive labor input. Therefore, land consolidation fails to affect agricultural labor productivity in these regions.

So land consolidation should be encouraged, at least in some high labor productivity regions where the cost of land fragmentation is high. On one hand, land consolidation may increase labor productivity and agricultural labor input. On the other hand, land consolidation is an important step for developing farm size and machinery application in the agricultural sector. As part of the urbanization process, more and more rural laborers are moving out of rural areas or agricultural occupations; land consolidation thus helps the remaining farmers enlarge plot size and adopt more efficient ways of cultivation.

Thus, a call for land consolidation is beneficial for farmers in regions where the marginal cost of land fragmentation is high and it is not urgent to consolidate farmland for the regions with a low marginal cost of land fragmentation. This implicitly suggests that the land reform policy should take the development of the local labor market into consideration. The next section will touch on the heated issue of land reform in China.

8.4 A discussion on land reform policy in China

The current land institution in China has been attributed with increasing land fragmentation resulting in insecure property rights. Thus, many economists have raised the prospect of a second round of land reform that would liberalize land property rights and facilitate the development of the land market (DEININGER and JIN, 2009; KIMURA et al., 2007; CARTER and YAO, 2002). However, this proposal has not met with a great deal of interest by policy-makers (DEININGER and JIN, 2009).

While recognizing the negative effect of land fragmentation, land reform policy should be concerned with facilitating land consolidation. However, enforced land consolidation is not a recommendable policy, as we have learned from the experiences of other south Asian countries (NIROULA and THAPA, 2005). A policy of land consolidation mainly benefits part-time agricultural households participating in both on-farm and off-farm work, while those agricultural households which lack or are incapable of accessing off-farm opportunities fail to benefit from it. Thus, enforced land consolidation may worsen the status of the poorest households due to lacking off-farm opportunities.

Further, enforced land consolidation may exacerbate poverty and inequality in the regions where the local labor and land marks are poorly developed, which is the opposite of the government's target. Agricultural households are usually the group with the least political power in a village; in this sense, land consolidation, which is largely conducted by the village cadre, may benefit rich households mainly pursuing non-agricultural work. For example, land with better soil fertility may be distributed to non-agricultural households, while agricultural households may receive a large piece of land in mountainous areas where the application of machinery is impossible.

Moreover, it is difficult to achieve a balance between equality and efficiency through enforced land consolidation in areas where soil fertility and irrigation conditions vary. The current fragmented characteristic of the farm structure equalizes the distribution of land resources within the community, since even farmland within a village is quite diversified, which has long been the second best choice for balancing between equality and efficiency. Land consolidation may be difficult to implement successfully if it involves high transaction costs due to many arguments and the unsatisfied attitude of some farmers. In 2005, the Chinese government issued an announcement concerning land development and land consolidation in order to increase the area of farmland and to promote agricultural production (MINISTRY OF LAND AND RESOURCES, 2005). Although the government has called for land consolidation for several years, a fragmented farm structure still prevails in China.

The analyses above show that enforced land consolidation is just another type of costly institutional distortion that cannot benefit all farmers and contribute to poverty reduction. One plausible approach to reducing land fragmentation in China is to consolidate farmland through the land market, which elicits a call for its liberalization. The land market may reduce land fragmentation only in those regions where the labor market is better developed and the marginal cost of land fragmentation is high.

One of the most important impediments to the development of the land market and to land consolidation through the land market is insecure land property rights due to land reallocation and constraints on land transactions. Due to the fear of expropriation, agriculturally productive investments by farmers are significantly suppressed (JACOBY et al., 2002; FEDER et al., 1992). Rather, the farmers invest more on farmland in the villages, where the risk is lower and an increase of land security may give rise to the confidence of farmers working on the plots to put more efforts towards soil fertility protection, for example, by applying more organic fertilizer and reducing the usage of chemical fertilizer (FENG et al., 2010; JACOBY et al., 2002; LI et al., 1998). Accordingly, an increase of land tenure security implies the development of low carbon agricultural production.

In the process of urbanization, many rural inhabitants move to cities to look for work opportunities. However, rural laborers temporarily or permanently participating in off-farm work have difficulty settling down in cities, or return back to their home villages frequently because they fear they could lose their farmland. DEININGER et al. (2004) observed that 8 % of villages would take back farmland from migrants who had rented out their land for a number of years. This land insecurity creates an obstacle for migration and can increase its opportunity costs (MULLAN et al., 2011; DE LA RUPELLE et al., 2009). On the other hand, land insecurity reduces the household's propensity to rent out land (KIMURA et al., 2007; DEININGER et al., 2005; CARTER and YAO, 2002), and the constraints on renting to outsiders decreases the amount of land on the rental market (JIN and DEININGER, 2009). Thus, the land reform policy that intends to liberalize the land market will contribute to an increase of migration and the prosperity of the land rental market.

At the same time, more secure land tenure helps to expand economic opportunities for farmers who do not join the off-farm work force (DEININGER et al., 2005). For instance, LOHMAR et al. (2001) found that the marginal product of land for households renting in land is 16.5 % higher than that for households that do not rent land. The land rental market provides a more convenient way to promote agricultural productivity and to consolidate land holdings without increasing poverty (JIN and DEININGER, 2009; DEININGER et al., 2005). Thus, land reform aiming to improve land security and the liberalization of the land rental market will contribute to land consolidation.

The land market policy of the Chinese government has recently displayed a tendency towards a reduction of administrative land reallocations at the local level and the permission of local land rental markets. The land tenure contract has been expanded from 30 years in 2002 (Rural Land Contract Law) to an unspecified "long term" in 2008 (3rd plenary meeting of the 17th Party Congress) and land reallocation is only allowed when two thirds of Villagers' representatives approved (WANG et al., 2011). This policy is supposed to facilitate unproductive farmers to transfer their farmland to the other farmers and assist voluntary land consolidation through land markets, thereby increase agricultural productivity. Indeed, land fragmentation was slightly reduced recently in China (TAN et al., 2006). Against this policy background, our findings have clear implications. If more liberal land market policies and hardened property rights will allow more consolidated farmland in the future, this will not trigger a flood of former farmers leaving rural areas in search for alternative incomes. As it makes farm work more productive, it will rather provide an incentive to continue farming and raise agricultural productivity.

8.5 Conclusions

This chapter discussed the current debates on the root causes of land fragmentation, the effects of land fragmentation, land consolidation and future land reforms in China. Land fragmentation in China stemming from a *quasi-demand* institutional innovation reduces agricultural labor productivity in the regions where the labor market is better developed and the marginal cost of land fragmentation is high. Thus, land policy reforms such as strengthening land property rights and developing the land rental market should be implemented in these regions to facilitate land consolidation and increase agricultural labor productivity. On the other hand, underdeveloped regions should concentrate on developing their labor market.

9 CONCLUSION

Land fragmentation is a widespread phenomenon in China and many other transition countries, but agricultural economists do not agree on its driving forces and effects. This monograph examines the current debates and provides an in-depth theoretical analysis and empirical study with respect to the determinants of land fragmentation and its effects on agricultural production and off-farm labor supply in China.

By tracing the history of land fragmentation, chapter 2 reveals that land fragmentation in modern China is not solely driven by either supply side or demand side forces, but rather comes from a *quasi-demand* institutional innovation. This means that the current land institution leading to land fragmentation stems from the farmers' demand for land decentralization, but at the same time is constrained by incomplete property rights. Thus, the current land institution may not increase the degree of land fragmentation when the labor market is underdeveloped. However, it may increase the degree of land fragmentation with the development of the labor market due to its suppression of the land market.

In chapter 6, we employ a translog production function in order to estimate the effect of land fragmentation on agricultural labor productivity. The findings show that land fragmentation decreases agricultural labor productivity in general. However, this effect varies with the marginal cost of land fragmentation and the development of the labor market. The negative effect of land fragmentation is obvious in regions with a higher marginal cost of land fragmentation and more off-farm opportunities such as Zhejiang, while it is not obvious in regions with a low marginal cost of land fragmentation and less off-farm opportunities, such as Hubei and Yunnan. These results are robust to time-invariant heterogeneity and cluster standard errors.

Chapter 7 further investigates the effect of land fragmentation on the off-farm labor supply. The outcome of our empirical study indicates that land consolidation has no impact on the off-farm labor supply. These results are robust to endogeneity, time-invariant heterogeneity, sample selection bias and the clustering of observations.

The policy implications of our findings and suggestions for future land reform policies are presented in chapter 8. We argue that rural development policies are not uniform across regions. Land tenure security and a more open land rental market should be enhanced in order to facilitate voluntary land consolidation through the land market and to increase agricultural labor productivity when the labor market is less constrained. With the development of the Chinese economy, the increase of labor demand in cities relates to structural transformation in rural areas. A call for land reform towards a more liberal land market becomes important to promote agricultural labor productivity in less constrained regions. However, a land consolidation policy cannot contribute to an increase of the off-farm labor supply.

This conclusion comes with one important caveat. The analysis in this monograph looked at a sample of continuously existing farms, operated either full-time or part-time. Farm exits were not considered. Improved opportunities to consolidate farmland due to better functioning land markets may at the same time convince some of the least productive farmers to give up farming altogether and earn their living fully from nonfarm sources. This process may well increase the number of urban job searchers and may lead to an increasing specialization and differentiation within the pool of Chinese rural households.

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APPENDIX

A.1 Variable list of STATA code

Table A-1: Variable list of STATA code

Variable	*Description*	*Unit*
outputrl	Total agricultural output	Yuan in 1995
landinp	Land input	Mu
laborinp	Labor input	Person days
capinp	Capital input	Yuan in 1995
plots	The number of plots on the farm	Plot
prov_id	The code of provinces, 33 is Zhejiang, 42 is Hubei, 53 is Yunnan.	
villg_id	The code of villages	
nhoush_id	The code of households	
year	The year of survey	
offlab	The total off-farm labor input of household	Person days
manulab	The off-farm labor input in manufactory industry	Person days
constlab	The off-farm labor input in construction industry	Person days
translab	The off-farm labor input in transportation industry	Person days
retlab	The off-farm labor input in retailing, restaurant and other services industry	Person days
beyhlab	The off-farm labor input beyond household-run business	Person days
manuincom	The off-farm income in manufactory industry	Yuan
constincom	The off-farm income in construction industry	Yuan
transincom	The off-farm income in transportation industry	Yuan
retincom	The off-farm income in retailing, restaurants and other services industry	Yuan
othinexp	The other household run business expense	Yuan
nh307	The off-farm income beyond household-run business	Yuan
nh308		Yuan
nh309		Yuan
nh310		Yuan
nh311		Yuan
nh314		Yuan
manuinexp	The off-farm expense in manufactory industry	Yuan
constinexp	The off-farm expense in construction industry	Yuan
transinexp	The off-farm expense in transportation industry	Yuan
retinexp	The off-farm expense in retailing, restaurants and other services industry	Yuan
othinexp	The other household run business expense	Yuan

Variable	*Description*	*Unit*
pesticpr	The pesticide price	Yuan
dist_rd	The distance of the village to main concrete road	km
aniper	The average income per capita in the village	Yuan
rentrate	The percentage of land in the village participating rental market	
houshsize	The number of people in the household	Persons
elem_hm	The number of people having elementary educational level	Persons
secon_hm	The number of people having secondary school educational level	Persons
hisch_hm	The number of people having high school educational level	Persons

A.2 STATA code for estimating production function

```
// Generate extreme values

ge extreme_output=0

centile outputrlif prov_id==33&year<2003, centile(25
50 75)

replace extreme_output=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003

centile outputrlif prov_id==42&year<2003, centile(25
50 75)

replace extreme_output=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003

centile outputrl if prov_id==53&year<2003, centile(25
50 75)

replace extreme_output=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003

ge extreme_landinp=0

centile landinp if prov_id==33&year<2003, centile(25
50 75)

replace extreme_landinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003

centile landinp if prov_id==42&year<2003, centile(25
50 75)

replace extreme_landinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003

centile landinp if prov_id==53&year<2003, centile(25
50 75)

replace extreme_landinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003
```

```
ge extreme_laborinp=0

centile laborinp if prov_id==33&year<2003, centile(25
50 75)

replace extreme_laborinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003

centile laborinp if prov_id==42&year<2003, centile(25
50 75)

replace extreme_laborinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003

centile  laborinp if  prov_id==53&year<2003, centi-
le(25 50 75)

replace extreme_laborinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003

ge extreme_capinp=0

centile  capinp if  prov_id==33&year<2003, centile(25
50 75)

replace extreme_capinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003

centile  capinp if  prov_id==42&year<2003, centile(25
50 75)

replace extreme_capinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003

centile  capinp if  prov_id==53&year<2003, centile(25
50 75)

replace extreme_capinp=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003

ge extreme_plots=0

centile plots if prov_id==33&year<2003, centile(25 50
75)
```

```
replace extreme_plots=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003

centile plots if prov_id==42&year<2003, centile(25 50
75)

replace extreme_plots=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003

centile plots if prov_id==53&year<2003, centile(25 50
75)

replace extreme_plots=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003

// Generate database

ge i_zhejiang=0

replace i_zhejiang=1 if    out-
putrl<extreme_output&landinp<extreme_landinp&laborinp<
extre-
me_laborinp&capinp<extreme_capinp&plots<extreme_plots&
prov_id==33&year<2003&outputrl>0&landinp>0&laborinp>0&
capinp>=0&plots>=1&elem_hm>=0&secon_hm>=0&hisch_hm>=0&
dist_rd>=0& pesticpr>0

ge i_hubei=0

replace i_hubei=1 if out-
putrl<extreme_output&landinp<extreme_landinp&laborinp<
extre-
me_laborinp&capinp<extreme_capinp&plots<extreme_plots&
prov_id==42&year<2003&outputrl>0&landinp>0&laborinp>0&
capinp>=0&plots>=1&elem_hm>=0&secon_hm>=0&hisch_hm>=0&
dist_rd>=0& pesticpr>0

ge i_yunnan=0

replace i_yunnan=1 if out-
putrl<extreme_output&landinp<extreme_landinp&laborinp<
```

```
extre-
me_laborinp&capinp<extreme_capinp&plots<extreme_plots&
prov_id==53&year<2003&outputrl>0&landinp>0&laborinp>0&
capinp>=0&plots>=1&elem_hm>=0& secon_hm>=0&
hisch_hm>=0& dist_rd>=0& pesticpr>0
ge i_pool=0
replace i_pool=i_zhejiang+i_hubei+i_yunnan
//Generate input and output variables
ge lnoutput=0
replace lnoutput=log(outputrl)
ge lnland=0
replace lnland=log(landinp)
ge lnlabor=0
replace lnlabor=log(laborinp)
ge lncapital=0
replace lncapital=log(capinp)
ge lnplots=0
replace lnplots=log(plots)
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
egen pmean_`x'=mean(`x') if i_pool
}
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
ge ps_`x'=0
replace ps_`x'=`x'-pmean_`x'
}
```

```
ge ps_llanlcap=0
replace ps_llanlcap=ps_lnland*ps_lncapital
ge ps_llanlplo=0
replace ps_llanlplo=ps_lnland*ps_lnplots
ge ps_lcapllab=0
replace ps_lcapllab=ps_lncapital*ps_lnlabor
ge ps_lcaplplo=0
replace ps_lcaplplo=ps_lncapital*ps_lnplots
ge ps_llablplo=0
replace ps_llablplo=ps_lnlabor*ps_lnplots
ge ps_lcapsqu=0
replace ps_lcapsqu=ps_lncapital^2
ge ps_llansqu=0
replace ps_llansqu=ps_lnland^2
ge ps_llabsqu=0
replace ps_llabsqu=ps_lnlabor^2
ge ps_lplosqu=0
replace ps_lplosqu=ps_lnplots^2
ge ps_llanllab=0
replace ps_llanllab=ps_lnland*ps_lnlabor
// Generate year dummies
forvalues x=1(1)7{
ge year_`x'=0
}
replace year_1=1 if year==1996
replace year_2=1 if year==1997
```

```
replace year_3=1 if year==1998
replace year_4=1 if year==1999
replace year_5=1 if year==2000
replace year_6=1 if year==2001
replace year_7=1 if year==2002
xtset nhoush_id year
xtreg ps_lnoutput ps_lnland ps_lnlabor ps_lncapital
ps_llablplo ps_lcaplplo  ps_llanlcap ps_lcapllab
ps_llanllab ps_lcapsqu ps_llabsqu ps_lnplots
ps_llanlplo  ps_llansqu ps_lplosqu year_* if
i_pool,fe
// Predict residuals
predict i_pred,e
// Generate a new data set
replace i_zhejiang=0 if i_pred==0|i_pred==.
replace i_hubei=0 if i_pred==0|i_pred==.
replace i_yunnan=0 if i_pred==0|i_pred==.
replace i_pool=0 if i_pred==0|i_pred==.
// Re-demean the variables based on the new data set
drop pmean_*
drop ps_*
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
egen pmean_`x'=mean(`x') if i_pool
}
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
```

```
ge ps_`x'=0
replace ps_`x'=`x'-pmean_`x'
}
ge ps_llanlcap=0
replace ps_llanlcap=ps_lnland*ps_lncapital
ge ps_llanlplo=0
replace ps_llanlplo=ps_lnland*ps_lnplots
ge ps_lcapllab=0
replace ps_lcapllab=ps_lncapital*ps_lnlabor
ge ps_lcaplplo=0
replace ps_lcaplplo=ps_lncapital*ps_lnplots
ge ps_llablplo=0
replace ps_llablplo=ps_lnlabor*ps_lnplots
ge ps_lcapsqu=0
replace ps_lcapsqu=ps_lncapital^2
ge ps_llansqu=0
replace ps_llansqu=ps_lnland^2
ge ps_llabsqu=0
replace ps_llabsqu=ps_lnlabor^2
ge ps_lplosqu=0
replace ps_lplosqu=ps_lnplots^2
ge ps_llanllab=0
replace ps_llanllab=ps_lnland*ps_lnlabor
//Generate provincial interactions
ge ps_zllablplo=0
replace ps_zllablplo=ps_llablplo if i_zhejiang
```

```
ge ps_hllablplo=0
replace ps_hllablplo=ps_llablplo if i_hubei
ge ps_yllablplo=0
replace ps_yllablplo=ps_llablplo if i_yunnan
// Estimate OLS model
reg ps_lnoutput ps_lnlabor ps_lncapital ps_lnland
ps_lnplots ps_llablplo
ps_llanlplo ps_llanlcap ps_lcapllab ps_lcaplplo
 ps_llanllab ps_llabsqu ps_lcapsqu ps_llansqu
ps_lplosqu year_* if year<2003&i_pool,
cluster(villg_id)
// Estimate FE model
xtset nhoush_id year
xtreg ps_lnoutput ps_lnlabor ps_lncapital ps_lnland
ps_lnplots ps_llablplo ps_llanlplo ps_llanlcap
ps_lcapllab ps_lcaplplo ps_llanllab ps_llabsqu
ps_lcapsqu ps_llansqu ps_lplosqu year_* if
year<2003&i_pool,fe cluster(villg_id)
 // Implement Hausman test
xtreg ps_lnoutput ps_lnlabor ps_lncapital ps_lnland
ps_lnplots ps_llablplo ps_llanlplo ps_llanlcap
ps_lcapllab ps_lcaplplo ps_llanllab ps_llabsqu
ps_lcapsqu ps_llansqu ps_lplosqu year_* if
year<2003&i_pool,fe
estimates store fe
xtreg ps_lnoutput ps_lnlabor ps_lncapital ps_lnland
ps_lnplots ps_llablplo ps_llanlplo ps_llanlcap
ps_lcapllab ps_lcaplplo ps_llanllab ps_llabsqu
```

```
ps_lcapsqu ps_llansqu ps_lplosqu year_* if
year<2003&i_pool,re
estimates store re
hausman fe re
// Generate time-demeaned variables
 sort nhoush_id year
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
by nhoush_id: egen dmean_`x'=mean(`x') if i_pool
}
foreach x in lnoutput lnland lnlabor lncapital
lnplots{
ge dif_`x'=0
replace dif_`x'=`x'-dmean_`x' if i_pool
}
ge dif_llanlcap=0
replace dif_llanlcap=dif_lnland*dif_lncapital
ge dif_llanlplo=0
replace dif_llanlplo=dif_lnland*dif_lnplots
ge dif_lcapllab=0
replace dif_lcapllab=dif_lncapital*dif_lnlabor
ge dif_lcaplplo=0
replace dif_lcaplplo=dif_lncapital*dif_lnplots
ge dif_llablplo=0
replace dif_llablplo=dif_lnlabor*dif_lnplots
ge dif_lcapsqu=0
replace dif_lcapsqu=dif_lncapital^2
```

```
ge dif_llansqu=0

replace dif_llansqu=dif_lnland^2

ge dif_llabsqu=0

replace dif_llabsqu=dif_lnlabor^2

ge dif_lplosqu=0

replace dif_lplosqu=dif_lnplots^2

ge dif_llanllab=0

replace dif_llanllab=dif_lnland*dif_lnlabor

ge dif_zllablplo=0

replace
dif_zllablplo=dif_lnlabor*dif_lnplots*i_zhejiang

ge dif_hllablplo=0

replace dif_hllablplo=dif_lnlabor*dif_lnplots*i_hubei

ge dif_yllablplo=0

replace dif_yllablplo=dif_lnlabor*dif_lnplots*i_yunnan

// Estimate time-demeaned model without regional dum-
mies

reg dif_lnoutput dif_lnlabor dif_lncapital dif_lnland
dif_lnplots dif_llablplo dif_llanlplo dif_llanlcap
dif_lcapllab dif_lcaplplo dif_llanllab dif_llabsqu

dif_lcapsqu dif_llansqu dif_lplosqu year_*  if
year<2003&i_pool, robust   cluster(villg_id) no-
constant

mat b=e(b)

scalar vadj=(e(N)-21)/(e(N)-1826-21)

matrix V=vadj*e(V)

eret post b V
```

```
ereturn display
// Estimate time-demeaned model with regional dummies
reg dif_lnoutput dif_lnlabor dif_lncapital dif_lnland
dif_lnplots dif_zllablplo dif_hllablplo dif_yllablplo
dif_llanlplo dif_llanlcap dif_lcapllab dif_lcaplplo
dif_llanllab  dif_llabsqu  dif_lcapsqu dif_llansqu
dif_lplosqu year_* if year<2003&i_pool, robust no-
constant cluster(villg_id)
mat b=e(b)
scalar vadj=(e(N)-23)/(e(N)-1826-23)
matrix V=vadj*e(V)
eret post b V
ereturn display
// Simulate output
predictnl sim_output=
exp((_b[dif_lnlabor])*ps_lnlabor+
(_b[dif_llabsqu])*ps_llabsqu+(_b[year_1])*year_1+
(_b[year_2])*year_2+(_b[year_3])*year_3+
(_b[year_4])*year_4+(_b[year_5])*year_5+
(_b[year_6])*year_6+(_b[year_7])*year_7+
pmean_lnoutput), ci(sim_loutput sim_uoutput)
//The relationship between labor input and aggregate
agricultural output
twoway (scatter sim_output laborinp) (scatter
sim_loutput laborinp) (scatter sim_uoutput laborinp)
if i_pool,by(year)
//Simulate MPL
```

```
predictnl sim_mpl=
(_b[dif_lnlabor])+(_b[dif_llablplo])*ps_lnplots if
i_pool,ci(sim_lmpl sim_umpl)

//The effect of land fragmentation on MPL

twoway (scatter sim_mpl plots) (scatter sim_lmpl plots)

(scatter sim_umpl plots) if i_pool

//Describe data

sort year

by year: sum outputrl laborinp capinp landinp plots if
i_pool&year<2003

sum outputrl laborinp capinp landinp plots if
i_pool&year<2003
```

A.3 STATA code for estimating off-farm labor supply function

```
//Generate off-farm labour supply
ge offlabour=0
replace offlabour= manulab+ constlab+ translab+ ret-
lab+ beyhlab
ge lnofflabour=0
replace lnofflabour=log(offlabour)
//Generate extreme values
ge extreme_offlabour=0
centile  offlabour if
prov_id==33&year<2003&offlabour>0, centile(25 50 75)
replace extreme_offlabour=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==33&year<2003
centile  offlabour if
prov_id==42&year<2003&offlabour>0, centile(25 50 75)
replace extreme_offlabour=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==42&year<2003
centile  offlabour if
prov_id==53&year<2003&offlabour>0, centile(25 50 75)
replace extreme_offlabour=r(c_3)+3*(r(c_3)-r(c_1)) if
prov_id==53&year<2003
//Generate offwage
ge housh_noagrincome=0
replace housh_noagrincome= manuincom+ constincom+ tra-
nincom+retincom+ othincom
ge housh_noagrexpen=0
replace housh_noagrexpen=  manuexp+ constrexp+ tran-
sexp+ retexp+ othexp
```

```
ge housh_noagrnetin=0

replace housh_noagrnetin= housh_noagrincome-
housh_noagrexpen

ge offincome=0

replace offincome=nh307+ nh308+ nh309+ nh310+ nh311+
nh314+housh_noagrnetin

ge offwage=0

replace offwage= offincome/offlabour if offlabour>0

ge lnoffwage=0

replace lnoffwage=log(offwage)

//Generate pesticide price

ge lnpestpr=0

replace lnpestpr=log(pesticpr)

//Generate land endowment varaible

ge aland=0

replace aland=landinp/houshsize

ge lnaland=0

replace lnaland=log(aland)

//Generate means of variables

sort nhoush_id year

by nhoush_id: egen promean1_houshsize=mean(houshsize)
if year<2003

by nhoush_id: egen promean1_lnplots=mean(lnplots) if
year<2003

by nhoush_id: egen promean1_lnaland=mean(lnaland) if
year<2003
```

```
by nhoush_id: egen promean1_elem_hm=mean(elem_hm) if
year<2003

by nhoush_id: egen promean1_secon_hm=mean(secon_hm) if
year<2003

by nhoush_id: egen promean1_hisch_hm=mean(hisch_hm) if
year<2003

by nhoush_id: egen promean1_rentrate=mean(rentrate) if
year<2003

by nhoush_id: egen promean2_lnpestpr =mean(lnpestpr)
if year<2003

by nhoush_id: egen promean2_aniper =mean(aniper) if
year<2003

by nhoush_id: egen promean2_ dist_rd =mean(dist_rd) if
year<2003

//Generate pool data set

ge i_npool=0

replace i_npool=1 if
i_pool&offlabour<=extreme_offlabour&offlabour>=0&

houshsize>0

xtivreg2 lnofflabour (lnoffwage= lnpestpr dist_rd
aniper) lnplots rentrate  houshsize lnaland elem_hm
secon_hm hisch_hm

year if year<2003&i_npool,fe

predict test_predict2,e

ge test_pool=0

replace test_pool=1 if
test_predict2!=.&test_predict2!=0

// Estimate sample selection probit model
```

```
probit test_pool lnplots rentrate lnpestpr aniper
unemployment houshsize lnaland dist_rd

elem_hm secon_hm hisch_hm promean*  if year==1995

predict pro_select95 if year==1995, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd

elem_hm secon_hm hisch_hm promean* if year==1996

predict pro_select96 if year==1996, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd

elem_hm secon_hm hisch_hm promean* if year==1997

predict pro_select97 if year==1997, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd

elem_hm secon_hm hisch_hm promean* if year==1998

predict pro_select98 if year==1998, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd

elem_hm secon_hm hisch_hm promean* if year==1999

predict pro_select99 if year==1999, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd elem_hm secon_hm hisch_hm
promean* if year==2000

predict pro_select00 if year==2000, xb

probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd elem_hm secon_hm hisch_hm
promean* if year==2001

predict pro_select01 if year==2001, xb
```

```
probit test_pool lnplots rentrate lnpestpr aniper
houshsize lnaland dist_rd elem_hm secon_hm hisch_hm
promean* if year==2002

predict pro_select02 if year==2002, xb

 //Calculate inverse Mills ration

foreach i in 95 96 97 98 99 00 01 02{

    ge imr`i'=0

    }

replace
imr95=normalden(pro_select95)/normal(pro_select95) if
year==1995

replace
imr96=normalden(pro_select96)/normal(pro_select96) if
year==1996

replace
imr97=normalden(pro_select97)/normal(pro_select97) if
year==1997

replace
imr98=normalden(pro_select98)/normal(pro_select98) if
year==1998

replace
imr99=normalden(pro_select99)/normal(pro_select99) if
year==1999

replace
imr00=normalden(pro_select00)/normal(pro_select00) if
year==2000

replace
imr01=normalden(pro_select01)/normal(pro_select01) if
year==2001
```

```
replace
imr02=normalden(pro_select02)/normal(pro_select02) if
year==2002

// Estimate FE-2SLS model

xtivreg2 lnofflabour (lnoffwage= lnpestpr dist_rd
aniper) lnplots rentrate houshsize lnaland elem_hm se-
con_hm hisch_hm

if test_pool,fe first cluster(villg_id)

// Implement Hausman test

xtivreg2 lnofflabour (lnoffwage = lnpestpr dist_rd
aniper) lnplots rentrate houshsize lnaland elem_hm se-
con_hm hisch_hm if test_pool,fe

estimates store fe

xtivreg2 lnofflabour (lnoffwage = lnpestpr dist_rd
aniper) lnplots rentrate houshsize lnaland elem_hm se-
con_hm hisch_hm if test_pool,re

estimates store re

hausman fe re

// Test for sample selection bias

ivreg2 lnofflabour (lnoffwage = lnpestpr dist_rd
aniper promean2_*) lnplots rentrate houshsize lnaland
elem_hm secon_hm hisch_hm promean1_* imr* if
test_pool,first partial(lnplots rentrate houshsize
lnaland elem_hm secon_hm hisch_hm) cluster(villg_id)

// Test for sample selection bias

test   imr95 imr96 imr97 imr98 imr99 imr00 imr01 imr02

// Test for fixed effects

test  (promean1_houshsize=0) (promean1_lnplots=0)
```

```
 (promean1_lnaland=0) (promean1_elem_hm=0) (pro-
mean1_secon_hm=0)  (promean1_hisch_hm=0) (pro-
mean1_rentrate=0)

// Estimate panel data sample selection model

ivreg2 lnofflabour (lnoffwage = lnpestpr dist_rd
aniper promean2_*) lnplots rentrate houshsize lnaland
elem_hm secon_hm hisch_hm promean1_* imr* if test_pool,
first partial(promean1_* imr*) cluster(villg_id)

//Describe data set

sum offlabour offwage  pesticpr dist_rd rentrate plots
houshsize aland elem_hm secon_hm hisch_hm aniper if
test_pool
```

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