The "New Rural Reconstruction": movement and sustainable agricultural development in China

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Thèse Nouveau Régime
Présentée et soutenue publiquement le 23 Octobre 2013
Pour l'obtention du titre de Docteur ès Sciences Économiques

Par

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Sous la direction de
Mme Pascale Combes Motel et Mme Mary-Françoise Renard

Membres du Jury

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La faculté n'entend donner aucune approbation ou improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à leur auteur.

Remerciements

CETTE thèse est le fruit d'un travail de cinq ans. Pendant ces jours et nuits, j'ai eu l'opportunité de travailler dans différents environnements : du bureau du CERDI en France au champ des villages en Chine. C'était une expérience enrichissante et unique qui m'a permise de rencontrer les gens et de comprendre la recherche. Cette thèse n'aurait pas vu le jour sans les contributions de nombreuses personnes que je tiens à remercier.

Tout d'abord, je remercie mes directeurs de thèse Pascale Combes Motel et Mary-Françoise Renard pour leur soutien et leur aide au cours de mes années au CERDI. Sans elles, je n'aurais jamais commencé cette thèse et mené la recherche sur le terrain. Bien évidemment, ce travail est aussi le produit de leurs suggestions pertinentes et relectures attentives.

Je remercie également les professeurs He Jie et Olivier Beaumais d'avoir accepté de rapporter cette thèse. Je remercie le professeur Nico Heerink d'avoir accepté de présider le jury de thèse, et Zhang Shiqiu et Luo Xubei d'en être les suffragants.

Cette thèse a été financée dans le cadre du programme Theilhard de Chardin soutenu par le Conseil Régional d'Auvergne et le Ministère des Affaires Etrangères de la France. Les recherches sur le terrain ont été financées par la fondation de l'Université d'Auvergne (UDA) et la municipalité de la ville de Clermont-Ferrand. Je tiens à exprimer ma reconnaissance au CERDI qui m'a accueilli. Mes remerciements vont au personnel administratif (Patrick, Annie, Martine, Odette) et à l'ensemble des professeurs, en particulier, Marcel fafchamps et Chen Yaobo qui m'ont beaucoup influencé et orienté dans mes recherches.

Le travail sur le terrain m'a permis de saisir l'importance du mouvement de "reconstruction rural" en Chine ainsi que des initiatives innovantes et des acteurs encourageants dans ce mouvement. Je remercie ici l'ONG The Partnerships for Community Development (PCD) et l'Institut de Recherche de Maïs de Guangxi (GMRI) pour m'avoir accueilli sur le terrain et pour leur collaboration dans la réalisation des enquêtes. Je remercie Huang Jieqing, Huang Kaijian, Qin Lanqiu, He Hong d'avoir facilité mes recherches. Je remercie particulièrement Bi Ailan, Xi Jixue et Su Yougan pour leurs aides et accompagnements tout le long de l'enquête. Bien évidemment, je remercie les nombreux villageois qui nous ont accueillis dans leur maisons et ont pris le temps de répondre à nos questions.

Bien entendu, je remercie mes amis et collègues du CERDI qui témoignent de notre amitié au cours de mes années au CERDI. Je pense à Xiong Hang, Chloé Duvivier, Alexandre Sauquet, Frédéric Aubery, Stéphanie Brunelin, Catherine Simonet, Christian Ebeke, Emilie Caldeira, Hélène Ehrhart, Gaoussou Diarra, Alassane Drabo, Romuald Kinda, Linguère Mbaye, Maelan Le Goff, Aurore Pelissier, Antoine Cazals, Florian Leon, Victor Béguerie, Joël Cariolle, Gwenole Le Velly. Je remercie en particulier, Sébastien Marchand, en plus d'être mon ami et collègue, d'avoir accepté de travailler avec moi. Notre collaboration m'a beaucoup aidé et a inspiré des projets encore plus ambitieux.

D'ailleurs, je remercie, du fond de coeur, François et Michelle Petit avec toute la grande famille de Montpellier qui m'ont nourri de grand amour, m'ont orienté vers la paix en soi, m'ont encouragé et soutenu jusqu'au bout. Je remercie également tous les amis français que j'ai rencontrés en France, en particulier, Philippe Jullien et Bernard Pierre Fenal, qui m'ont donné le goût de la France et de la culture française. Sans eux, rien n'aurait été pareil.

Pour terminer, cette thèse n'aurait pas eu lieu sans l'appui de ma famille et des proches. Un immense merci à mes parents pour leur amour profond et leurs soutiens absolus. Un gros bisou à Xi, pour sa présence, patience et émotion dans ma vie.

Je dédie ce travail à la mémoire de mon père, qui m'a quitté trop tôt pendant ma thèse. Mais il reste, dans mon coeur, ma source de courage.

RÉSUMÉ

Cette thèse étudie le mouvement de la Nouvelle Reconstruction Rurale (NRR) sous l'angle du développement durable, en prenant l'exemple concret du village de Sancha, une communauté rurale de la province du Guangxi en Chine. Initié en 2003, la NRR est un réseau national de projets de développement qui réunit des intellectuels, des étudiants et des organisations dont l'objectif est d'expérimenter différents modèles de développement agricole et rural en Chine. Comme alternative à l'industrialisation agricole, la NRR favorise la coopération entre les petits agriculteurs, le savoir-faire local et l'agro-écologie pour le développement durable de l'agriculture. Afin de comprendre ses caractéristiques institutionnelles, son fonctionnement et son impact, nous avons mené une enquête dans le village de Sancha pour collecter des données sur les comportements socio-économiques de petits exploitants agricoles, et proposé trois études de cas sur la NRR.

Nos analyses empiriques suggèrent que la NRR a promu le développement de l'agriculture biologique dans le village. Les activités sociales sont efficaces pour la construction du réseau social via lequel l'agriculture biologique a été diffusée rapidement. Néanmoins, sans la formation technique suffisante et continue, les paysans récemment convertis à l'agriculture biologique tendent à surutiliser l'azote et perdent leur avantage environnemental dans la riziculture. Pour améliorer la performance des petits paysans, l'apprentissage participatif social paraît utile mais limité car les petits agriculteurs sont plutôt tirés par la performance économique que par la protection environnementale. De ces résultats, nous recommandons un partenariat Etat-société civile qui combine les services d'extension agricole du gouvernement et la reconstruction rurale ascendante pour l'objectif commun d'une agriculture durable en Chine.

Mots-clés : Nouvelle reconstruction rurale, Agriculture durable, Agriculture biologique, Chine.

ABSTRACT

This doctoral thesis studies the New Rural Reconstruction (NRR) movement from a sustainable development perspective, through a concrete case of Sancha village, a rural community in China's Guangxi province. Initiated in 2003, the NRR is a grassroots network of development projects which unites intellectuals, students and organizations to experiment with different models of agricultural and rural development in China. As an alternative to agricultural industrialization, the NRR favors the cooperation of smallholder farmers, local knowledge and agro-ecology for sustainable agricultural development. In order to understand the NRR's institutional characteristics, functioning and impact, we conducted a survey in Sancha village to collect data on smallholder farmers' socio-economic behavior and performed three in-depth NRR case studies.

Our empirical analysis suggests that the NRR has promoted the development of organic farming in the village. Social activities are cost-effective for social network building where organic farming is diffused rapidly. Nevertheless, without sufficient, ongoing technical training, farmers newly converted to organic farming tend to overuse nitrogen and lose their environmental advantage in rice production. To improve the performance of smallholder farmers, participatory social learning appears useful but limited because smallholder farmers are interested in economic performance rather than environmental protection. On basis of these results, we recommend a state-civil society partnership which combines the government's agricultural extension services and bottom-up rural reconstruction for the common objective of sustainable agriculture in China.

Keywords: New rural reconstruction, Sustainable agriculture, Organic farming, China.

Table of contents

Photo 1. Overview of research village

Source: Photo taken by author in 2010

General introduction

Global food security and sustainable agriculture

Food security, defined as when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life, is the top priority for modern agricultural development (World Food Summit, 1996). In the projections made by the Food and Agriculture Organization (FAO) for the period of 1999 to 2030, global agricultural production will increase by 56 percent, with arable land expansion accounting for 21 percent of production growth in developing countries. Meanwhile, the share of irrigated production in developing countries is projected to increase from 40 to 47 percent (Alexandratos et al., 2006). In spite of such ambitious projections, the objective of global food security appears out of reach. The 32nd session of the Committee on World Food Security acknowledged that the World Food Summit's target of halving the number of hungry people by 2015 will not be met in light of the present models of agricultural development and global environmental changes (FAO, 2006).

It has been long recognized that modern agriculture derives an increasing proportion of its energy supplies from non-renewable sources and has an increasingly detrimental impact on the environment. This is particularly reflected in its heavy reliance on chemical fertilizers and pesticides and its external costs to the ecosystem and human health (Hodge, 1993). Numerous studies have quantified the scale of the costs and warned about the non-sustainability of modern agriculture (Steiner et al., 1995; Pimentel et al., 1995; Pingali and Roger, 1995; Norse et al., 2001; Pretty and Ball, 2001). More recently, new concerns about global climate change, food price fluctuation and the impact of bio-fuels competition on agricultural production and food availability have stimulated broader interest in achieving long term food security through alternative paradigms for agricultural development (Gregory et al., 2008).

In this context, the concept of sustainable agriculture was put forward by international society in the *Agenda 21* of 1992. Ikerd (1993) defines sustainable agriculture as a system that is capable of maintaining its productivity and usefulness to society over the long run. In principle, the aims of sustainable agriculture are 1) to integrate natural processes (e.g. nutrient cycling, nitrogen fixation, soil regeneration and natural control of pests) into food production processes; 2) to minimize the use of non-renewable inputs that damage the environment or harm human health and welfare; 3) to make productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly inputs; 4) to make productive use of people's capacities to work together to solve common agricultural and natural resource problems, such as pest, watershed, irrigation, forest and credit management. Under this definition, alternative agriculture models such as organic farming , low input agriculture, agroecology, permaculture and climate-smart agriculture have been revived (Scofield, 1986; Edwards, 1987; Altieri et al., 1995; Mollison et al., 1991; Branca et al., 2011).

In spite of the common objectives, there is no single pathway for achieving sustainable agriculture and the solutions are often different in developed and developing countries. Academic research on this alternative paradigm of agriculture is far from enough to support its promising development. In 2008, an international conference on "food security and environmental change" held at the University of Oxford claimed a new integrated, multi-disciplinary research agenda on key issues such as solutions beyond technology to increase agricultural yields, tradeoffs across multiple production scales, social and cultural values in agricultural production, scenarios of adaptation to socio-economic and environmental changes, food price volatility and sustainable agriculture governance, especially in developing countries.

The dilemma of Chinese agricultural development

As the world's most populous developing country, China is playing an influential role in terms of food security on the international scene. The development of sustainable agriculture is thus particularly relevant in China. Due to scope limitations, this thesis will focus on China's domestic development of sustainable agriculture. Chinese agricultural development constitutes a good illustration of the dilemma of balancing food security and environmental conservation, also faced by other developing countries. As a resource-poor country, China needs to feed its growing population of 1.3 billion (19% of the world's population) with only 112 million hectares of agricultural land (9% of the world's agricultural land)[1]. Throughout China's long history, food shortages have been frequent. For instance, just 50 years ago, in the context of governmentally imposed collective farming, the "1959–1961 Great Famine" caused about 30 million deaths and remains a painful memory in China today[2] (Lin, 1990).

Chinese intensive agricultural development

To achieve food security at the national level, China has opted for intensive agricultural development during the past decades. Influenced by the "green revolution", China has heavily subsidized the production and consumption of chemical fertilizers to improve agricultural yields

[1]Data source: World Development Indicator 2011.

[2]In the 1950s, Chinese agriculture was characterized by a collective farming system that dominated by the people's communes. This cumbersome top-down system failed to secure food production and collapsed after the "1959–1961 Famine".

(Nyberg and Rozelle, 1999). For instance, it is estimated that for production of nitrogen fertilizer only, the government has awarded about 20 billion yuan in subsidies in 2006 (Cheng et al., 2010). As a result, the use of chemical fertilizers for agricultural production increased about 6 fold between 1980 and 2011. And nitrogen fertilizer has increased 2.5 fold during the same period (NBSC, 2011). The intensive use of chemical fertilizers was the largest contributor in physical inputs to agricultural growth in China, representing 21.7% of the agricultural growth from 1965 to 1993 (Fan, 1997).

China has also invested heavily in irrigation facilities for its agricultural production. The percentage of arable land under irrigation increased from 18% in 1952 to approximately 50% in 2007, consuming more than 80% of the total national water use (Han, 1989; Huang and Rozelle, 2009). Specifically, groundwater resources were exploited for irrigation. Since the 1990s, the water market has been privatised so that irrigation equipment such as pumps and wells are owned and managed by farmers who are allowed to pump water from their wells and sell it to other farmers (Wang et al., 2009). Investment in irrigation systems has been shown to increase farmer productivity and contribute significantly to food production (Nyberg and Rozelle, 1999; Huang et al., 2006).

In the mean time, agricultural development was also accompanied by substantial efforts towards technological progress. In the mid-1980s, a nationwide reform in R&D was launched. The government's investment nearly tripled between 1990 and 2005 (Jin et al., 2002; Huang et al., 2010). The R&D was translated into two main technology innovations: the use of hybrid seeds and changes to the multi-cropping system, which have become the primary engine of the Total Factor Productivity (TFP) in Chinese agriculture (Fan and Pardey, 1997; Xu, 1999). For example, from 1975 to 1990, the technological change contributed to 60% of the increase in rice productivity, in which the use of hybrid seeds accounted for 49% and the change in cropping system accounted for about 11% (Huang and Rozelle, 1996).

As a result of these efforts, Chinese agricultural development has achieved great success. For instance, the output of grains grew from 273 megatons in 1978 to 520 megatons in 2011, an increase of approximately 90%, of which rice yields almost doubled, and the maize and wheat yields almost tripled from 1978 to 2011. The grain self-sufficiency rate in China is maintained at about 90%. In addition to grain production, China produces about 62% of the world's aquaculture products, 29% of the world's meat and 50% of the world's vegetables[3]. China's agricultural development has not only ensured the food security of 1.3 billion people and improved people's living standards but has also made a significant contribution to the world's food security.

[3]Calculation based on FAO statistics.

Chinese agricultural pollution and environmental crisis

Although much has been achieved by this spectacular agricultural development, China is putting tremendous pressure on its limited natural resources and has generated dramatic consequences on the agro-environment. Consequently, the country is facing serious agricultural pollution and food safety problems, which are widely documented and analyzed in the literature.

Overuse of fertilizers and pesticides

First is the excessive use of chemical fertilizers and pesticides. During the reform period, the public investment in agricultural extension services shrunk sharply. The agricultural extension systems, which are used to transfer and monitor new agricultural technology, collapsed drastically. Consequently, extension workers were forced to be self-funding and rely on the sales of fertilizers and pesticides (Huang et al., 2004a; Jin et al., 2009). It is now recognized that without effective extension services and regulation, farmers' application of fertilizers and pesticides are often unbalanced and application rates are excessive from both a biological and an economic perspective. Moreover, the lack of coordination between agricultural and environmental policies and the structural change of agricultural production drive the overuse of modern inputs in China.

According to the statistics of the FAO, China uses 35% of the world's chemical fertilizers for its agricultural production, making it one of the most fertilizer-intensive agricultures in the world. Specifically, China's average fertilizer consumption on cultivated land is 357 kg per hectare, which is twice the maximum amount of fertilizer consumption in developed countries. Nitrogen fertilizer consumption is 171 kg per hectare, 2.5 times higher than the world average. Phosphate fertilizer consumption is 57 kg per hectare, about 2 times higher than the world average. These statistics imply that fertilizers are being largely overused in China (Zhao et al., 2008).

Moreover, China is also the largest pesticide consumer in the world. The total amount of pesticide consumption increased from 0.86 megatons in 1983 to 1.33 megatons in 2003 (Zhang et al., 2004). According to studies of the Chinese Academy of Agricultural Sciences, 40% of pesticide used in rice production and 50% in cotton production are superfluous. More serious is the fact that part of the widely used pesticides are noxious to a degree which is banned in other countries (e.g. methamidophos, dimethoate, parathion, methylparathion and dichlorphos). Farmers are thus exposed to high health risks and poisoning incidents are frequent in rural areas.

This high application of chemical inputs is generally 10-50% above crop nutrient needs, and the residues are released into the environment. According to the China Council for International Cooperation on Environment and Development, approximately 1.23 megatons of nitrogen are discharged annually into Chinese rivers and lakes, 0.49 megatons into groundwater and 2.99

megatons into the atmosphere. The overuse of fertilizers has caused a high level of Non-Point Source (NPS) pollution from agriculture production in China (Zhang et al., 2004; Liu et al., 2005).

Land degradation and soil erosion

Due to the dominant use of chemical fertilizers, traditional practices of soil fertility maintenance such as green manure plantation, returning straw back to fields and use of animal manure as fertilizer are gradually being abandoned. Therefore, chemical fertilizer-based NPS pollution has direct consequences on agricultural land, e.g. soil crusts and salinization, soil structure decline and erosion, organic matter and soil fertility loss. According to the statistics of national soil erosion surveys, about 40% of Chinese land is affected by erosion, mostly wind erosion (Heerink et al., 2009). The eroded land share is more than 3 times the world average, 2.4 times higher than in the rest of Asia, almost 3 times higher than in Africa, and 7 times higher than in North-America and Oceania (Huang, 2000).

About one third of the cultivated land suffers from erosion, and the fertility and quality of cultivated land declined in most Chinese regions between the 1950s and 1980s (Yang, 1994; Lindert, 1999), especially in mountainous and hilly areas which represent future potential agricultural production sites of China. In fact, the land degradation and soil erosion has a direct impact on Chinese agricultural production. As shown by Huang and Rozelle (1995), from 1975 to 1990, grain yield in China decreased by 19.1% due to soil erosion, by 0.2% due to salinity, and by 11.1% due to multiple cropping intensity. More seriously, the land degradation has resulted in natural disasters. For instance, in the areas of the lower reaches of the Yangtze river, irrational land reclamation of the flood diversion area for agricultural use has led to the reduction of the river's flood discharge capacity, which contributed to the 1998 flood disaster (Zhang, 1999).

Water shortage and pollution

The agricultural stress on water resources and poor water quality are additional concerns in China. Studies show that the average availability of renewable water resources (surface water and groundwater) in China declined from 2,849 m3 per person per year in 1980 to 1,785 m3 in 2009 (Qu et al., 2011). It is only one-third of the average of the developing countries and only one-fourth of the world average (Shalizi, 2006). The distribution of water resources in China is highly unequal, i.e. water abundance in the south (3208 m3 per person) and severe water scarcity in the north (757 m3 per person). Facing the growing scarcity of surface water, groundwater resources have been over–exploited in the north. For instance, The number of tube-wells used for irrigation has increased from 0.2 million in 1963 to 5.2 million in 2007, 95% of which were in the north (Zhang and Ge, 2008).

As a result, groundwater tables are falling and many wells are being pumped dry in northern

China. Official statistics of the North China Plain show that during the period 2000-2007, the groundwater level declined in 61% of the monitoring sites (Ministry of Water Resources, 2008). In the most severe case, Hai basin, groundwater level declined between 10 and 50 m in the areas surrounding Beijing, Shijiazhuang and Tangshan (WorldBank, 2002). Also, groundwater depletion has taken place in the south where surface water is polluted, e.g. the lower reaches of the Yangtze. It is estimated that 25 billion m3 of non-rechargeable deep-aquifer groundwater in the area were mined in 2000, mainly for agricultural production (WorldBank, 2007).

The severe water shortage also results from widespread water pollution and eutrophication. Mainly caused by fertilizers (nitrogen and phosphorous) and pesticides runoff from cultivated land and infiltration of livestock waste, the NPS pollution and eutrophication of Chinese lakes and water system are serious (Zhang et al., 2004; Liu et al., 2005; Xie, 2009). According to a survey conducted between 1989 and 1993, among 131 sample lakes in China, 51.2% were classified as excess-nutrient lakes and are no longer suitable as freshwater sources without treatment. In the north, only 40% of monitoring sites can provide fresh water for human consumption after treatment (Ministry of Environmental Protection, 2009). In coastal areas, falling groundwater levels due to over-exploitation caused migration of poor-quality groundwater into good-quality aquifers and caused intrusion of salty seawater. Salt water intrusion in coastal aquifers was found to be common in some 72 coastal areas covering a total area of 142 km2 (WorldBank, 2002).

Soil contamination and food safety problem

A more recent concern is the increasing soil contamination by heavy metals. According to the Chinese State Council Development Research Center, roughly 20% of Chinese agricultural land has already been contaminated by toxic heavy metal (CSCDRC, 2006). Yet, no precise data is published to evaluate the severity of the soil contamination in China. Some anthropogenic sources of pollution have been identified, including chemical fertilization, animal waste and pesticide application, sewage irrigation, industrial pollution, mining and smelting and atmospheric deposition. Agricultural activities are responsible for 79.6%, 56%, and 63% of the total annual inventory of Copper (Cu), Zinc (Zn), and Cadmium (Cd) in agricultural soils (Chen et al., 1999; Luo et al., 2009). In terms of spatial distribution, central, southwest and east China showed the most contamination of Lead (Pb), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Copper (Cu), and Antimony (Sb). The hot-spots of Cobalt (Co) were in east China, whereas those of Magnesium (Mg) were within northwest and Central China. In addition, the northwest region also showed high levels of Manganese (Mn) and Calcium (Ca) in the soil (Niu et al., 2013).

The elevated level of heavy metals in cultivated land not only decreases the productivity and quality of crops, but also threatens the safety of the ecosystem and public health through food intake (Chen et al., 1999; McLaughlin et al., 1999). For instance, it has been reported that the rice production in southern China has been threatened by elevated heavy metals in the soil in recent years. Results of a survey by Nanjing Agricultural University showed that 10% of rice samples collected from six agricultural regions were tainted by Cadmium (Cd) (Zhen et al., 2008). Another investigation in the coastal region of the Fujian province showed that more than 16% of rice samples exceeded the safety levels for lead, and more than 11% exceeded the levels for cadmium (Xie et al., 2008). More recently, an investigation of rice markets in southern China showed that 70% of the tested rice samples have found elevated level of Cadmium (Cd) (Zhang et al., 2009). The soil contamination and food safety problem are becoming an urgent strategic task for sustainable agriculture in China.

Policy transformation: from quantity to productivity

It is now widely agreed that the rapid decline in natural resources and the continued degradation of the agro-environment can not sustain agricultural development and will endanger China's long-term food security. A sustainable agriculture system with equal emphasis on food security and environmental protection has become an apparent objective in the *China 21st Century Agenda* (National Planning Committee, 1994). The objective is formulated in the government's 11th Five-Year Plan as building a resource-conserving and environmentally-friendly society (National Development and Reform Commission, 2006). Guided by the objective of sustainable development, a policy transformation in agricultural development is occurring today in China.

During the reform period of 1970s-1990s, China's agricultural policy was marked by the "Household Responsibility System" (HRS) reforms which had broken the collective farming system and redistributed the collective-owned land to farmers and ensured their de facto food sovereignty and economic autonomy[4] (Lin, 1992, 1997). Farmers' incentives for agricultural production were thus strongly stimulated and agricultural output grew by 35%–60% (McMillan et al., 1989; Lin, 1997; Huang and Rozelle, 1996). Following the growth of agricultural output, the mandatory grain procurement system was replaced by a market-based procurement system and food markets were liberalized. The food markets have become highly integrated since the late 1990s, which has induced substantial structural change in agricultural production, i.e. from prevalent grain production to diversified cash crops and livestock production (Huang and Rozelle, 2006). Other reforms such as food pricing control reform and opening to international trade were also undertaken mainly for the objective of stimulating agricultural production.

With a new objective of environmental protection, China has shifted its policy direction to implement nationwide ecological restoration programs such as the "Grain for Green" program since 1999[5] (Ministry of Land and Resources, 2004; Feng et al., 2005; Deng et al., 2006). The program generally uses a top-down public direct payment scheme to convert cropland on steep slopes in the upper reaches of the Yellow and Yangtze River Basins back to forest land

[4]The property of land remains collective.

[5]It is also known as the Sloping Land Conversion Program (SLCP).

and natural grassland (Liu et al., 2008; Qu et al., 2011). Studies show that the program has achieved significant and positive ecological outcomes and has had a moderate impact on poverty alleviation (Xu et al., 2006; Liu et al., 2008). Nevertheless, it has also been observed that the program has caused accelerated decline of cultivated land since 2000, which has appeared to jeopardize food security (Tan et al., 2007). Convincing evidence also indicates that the program contributed to a worsening of wind erosion in semiarid regions in China (Cao, 2008). As a result of the conflict between food security and environmental protection, the expansion of the ecological program was slowed down and finally ended in 2009 (Ministry of Land and Resources, 2010).

To date, for a balanced compromise between food security and environment protection objectives, China stresses agricultural productivity through land regime reform, agricultural modernization and agricultural R&D. Under the principle of equal access to land, land ownership still remains collective in China. Within the collective-owned scheme, farmers' right of agricultural land exploitation is contracted for 30 years. In 2006, the Rural Land Contract Law clarified farmers' rights to lease and exchange their land. This land reform aims to encourage transfers and concentration of land to facilitate large scale agricultural production. Moreover, current debates exist around more thorough land privatisation, which would allow farmers to sell their land. It is assumed that land privatisation would accelerate land concentration and the shift of surplus rural labor, thus increasing agricultural labor productivity and improve the well-being of rural labor (Huang and Rozelle, 2009).

With respect to agricultural modernization, an industrialized model (mechanization) has been promoted to Chinese agriculture to increase productivity. According to the statistics of the Chinese Ministry of Agriculture (MOA), China invested 13 billion Yuan to support farmers buying farm machinery in 2008. The total power of farm machinery reached 821.9 million kw and the mechanization level was 45.8%, with a target of 70% by 2020. By realizing agriculture mechanization, the government aims to substitute agricultural labor force by machinery power and shift to a specialized and large scale production system as in many developed countries.

Finally, agricultural R&D continues to be the most important engine of productivity and public investment has increased rapidly during the past decades (Rozelle et al., 1997; Jin et al., 2002; Huang et al., 2010). After the Hybrid variety seeds, the government now invest in the biotechnology to develop biotech varieties (Huang et al., 2004b). For instance, since the commercialization of genetically modified cotton (Bt cotton) in the late 1990s, biotech cotton varieties have spread across the country. Nowadays, about 2/3 of cotton in China is Bt variety. The commercialization of biotech staple grain seeds, which is currently prohibited, is under debate, and viewpoints appear to differ greatly within the government as well as in public opinion.

It is obvious that China is pursuing a model of industrialized modern agriculture for the objective of sustainable development. It appears natural for the government to follow the paradigm of most developed countries to deepen land reform, mechanize agriculture production and boost technology innovation. Current policies are designed to make Chinese agriculture more productive and competitive. However, it's still worth asking the questions: Is the government's top-down policy and state-mandated technological improvements efficient to pursue long-term food security? Is technology-driven productivity sufficient to restore the agro-environment? Is industrialization the only solution to developing sustainable agriculture in China?

New Rural Reconstruction: alternative response from civil society

As a response to the state's overwhelming policy of agricultural modernization, Chinese civil society (i.e. scholars, social and environmental activists, NGOs and students) is moving towards an alternative sustainable agricultural and rural development system. Instead of industrializing the agriculture, alternative thinking stresses that peasantry is at the core of agricultural development and sustainable agriculture should be peasant-centered (Wen, 2007; He, 2007; Pan and Du, 2011a,b).

With approximately 70% of the population registered as rural, China is an agricultural society[6]. Most of the rural population are smallholder farmers which maintain social links with the countryside and agriculture. Their links with agriculture are expected not only to alleviate employment pressure but also to serve as a safety net for food price shocks and economic fluctuation (De Janvry and Sadoulet, 2011). The shift of large rural populations out of agriculture will cut these links and make market the only access to food. Rural people's food security is thus likely to be more vulnerable to economic fluctuations and soaring food prices. Instead of improving food security, the shift of rural populations only sweeps dust under the carpet and exacerbates the problem.

In the foreseeable future, smallholder agriculture will remain prevalent in China given the large rural population and limited arable land. According to recent FAO statistics, there are close to 200 million smallholder farmers in rural China. The average farm size is under 0.5 hectares (Fan and Chan-Kang, 2005; Swaminathan, 2013; Bélières et al., 2013). Although smallholder agriculture is usually judged as backward, its contribution to food security, bio diversity, environment protection and natural resource conservation are outstanding and have raised more and more attention (Garrity et al., 2010; Swaminathan, 2013; Kull et al., 2013). In contrast, the industrialized monoculture is criticized as the source of problem rather than a solution. For instance, the takeover of land by monocultures causes rural depopulation, destroying local community life and local economies. It also upsets the local ecological balance, causing outbreaks of illnesses and negative feedback cycles. To maintain the high productivity, monoculture requires even more chemical fertilizers and pesticides. Food security at the expense of high fossil energy consumption is unsustainable given China's constraints in energy

[6] According to the National Bureau of Statistics, about 50% of the Chinese population resides in cities and towns in 2012. Yet the registered population with rural Hukou account for about 70% of the total population.

production and CO_2 emission.

While technology is an engine of productivity, it is also a two-edged sword. The use of modern inputs and irrigation in Chinese agriculture provide good illustrations. On one hand, the use of modern inputs and irrigation has boosted the agricultural output in China. On the other hand, the overuse of modern inputs and irrigation has generated severe environmental problem. Obviously, good technology can also generate adverse impact if farmers use it in an unsustainable way. Therefore, technological progress must be accompanied by farmers skill development, which will ensure appropriate use of new technology.

Therefore, farmers are the most important assets of Chinese agriculture and also the key solution for sustainable agriculture. Effective and adaptive human development is a natural sustainable engine of agricultural development. The problem is that smallholder farmers are often undervalued in China due to their large population, low education level and poor economic condition. Since the reform era, they have been atomized and overexploited under the industry-biased policy. Political and market distortion have seriously hurt their agricultural interests and expelled them from agriculture. If the role of smallholder farmers is now recognized as crucial for sustainable agricultural development, the question remains "how" (Thapa and Gaiha, 2011; Swaminathan, 2013). How to revive the vitality of smallholder agriculture? How to organize smallholder farmers in atomized Chinese rural society? And how to empower them with the resources for sustainable and environmentally friendly technology?

All the answers to these questions are currently under experimentation entitled "New Rural Reconstruction (*Xin Xiangcun Jianshe*)" (NRR) in villages across China (Thøgersen, 2003; Day, 2008; Pan and Du, 2011a,b). Without official data, the NRR is seldom studied and understood in the economic literature. However, it deserves rigourous investigation and could derive rich implications for sustainable agricultural development in China as well as in other developing countries. Curious to discover its origin, mechanism and impact, I decided to get involved and conduct a fieldwork-based economic research to shed light on this grassroots rural movement in China.

Objectives of the thesis

The objectives of this thesis are to sketch the NRR movement in China and to demonstrate its potential for sustainable agricultural development. Firstly, beyond the historical review and general description, we aim to examine a recent precise and comprehensive NRR experiment. To this end, an NGO-led NRR experiment in Guangxi province was identified and a six-month field research project was conducted in the village of Sancha to gather detailed information with respect to social organization and sustainable agricultural development in the village. This very first hand data is original and reliable for in-depth case studies of the NRR.

Secondly, specific social approaches of the NRR are under investigation to ascertain the effectiveness and limitations of this alternative model of rural development. On the basis of economic theories and micro level investigation, we attempt to provide empirical evidences about the social and economic foundation of the NRR approaches. This approach allows us to cross sociological and economic aspects of sustainable agriculture and make a contribution to its scenario design in developing countries.

Thirdly, this thesis contributes to current agricultural and rural reform in China. By drawing on the experience of the bottom-up NRR, we expect to derive relevant implications for the government's ongoing policy of "New Socialist Countryside Construction". New institutions and policy recommendations with respect to farmers' organization, education and environmentally friendly technology development are needed to support government policy transformation and influence the impact of policy in the desired directions.

Finally, the studies of Chinese NRR movement will provide reference for similar rural initiatives in other developing countries. As part of the global peasant movement network, the Chinese reference is valuable to promote international exchange and cooperation for peasant development. This thesis thus serves as an open window to the world in the hope of attracting more attention on bottom-up rural initiatives for sustainable development in developing countries.

Outline of the thesis

For the organization of thesis, **Chapter 1** provides a historical review and an inventory of current NRR movement in China. This information is necessary to understand the NRR development and the context of our research. It is followed by the presentation of the field work in Sancha village. We provide background information about the field work as well as the socio-economic conditions of the village. The methodology of the field work, i.e. the design and the implementation of the rural household survey, is discussed in details. Also, the data collected by the survey is briefly discussed in this chapter. Chapter 1 thus serves as a starting point and constitutes a solid basis for the following empirical analysis. In the following chapters, we provide three case studies with respect to the distinct approaches of the NRR movement, i.e. social reconstruction, organic farming development and participatory social learning.

Chapter 2 discusses the original approach of social reconstruction employed by the NRR experiment to promote sustainable agriculture. A concrete example in Sancha village is surveyed to illustrate this approach, i.e. organic farming is promoted through basketball matches. To investigate the social mechanism underlying this approach, quality research has been done to understand farmers' motivation for organic farming and the role of basketball matches in the social life of the village. This qualitative research derives a testable hypothesis of social network building via basketball matches in the village. We then model the social network according to this hypothesis and identify the social network effect on farmers' adoption of organic farming using a panel structure household survey data. Following the discussion in the literature of social network economics, a novel Heckman-IV method is adopted for the identification of endogenous social network effect.

The identification result confirms a large social multiplier effect in the diffusion of organic farming within the social network, which has proved the efficiency of social reconstruction (e.g. via basketball matches) in the promotion of sustainable agriculture in small village. In addition, the regression analysis also identify women, education and labor as determinant factors for organic farming development, whilst off-farm activities are in competition for organic farming. This case study demonstrates that in small, poor and labor abundant village, the social activity is a cost-effective mean to achieve farmers' collective action for organic farming development.

If the adoption of organic farming is *a priori* environmentally sound, its sustainability with respect to food security and environment protection is still under hot debates. **Chapter 3** thus aims to evaluate the sustainability of organic farming in the NRR framework with an indicator of Environmental Efficiency (EE) as proposed by Reinhard et al. (1999). This EE indicator is defined as the minimum use of pure nitrogen as environmentally detrimental inputs at given output level and measures the resource efficiency of smallholder farmers, which is relevant in the Chinese context of nitrogen fertilizer overuse. Using plot-season level survey data, we calculate the EE within the framework of Stochastic Frontier Analysis (SFA) for smallholder paddy rice production. We then compare the EE between non-certified organic farming and conventional farming systems using a standard econometric approach.

We obtain two "surprising" findings with this exercise. First, we reject the hypothesis of the existence of a "technology gap" between organic and conventional farming systems in smallholder environment. Farmers could easily substitute chemical fertilizers by organic fertilizers on small plots and realize similar yields in our case. Second, organic farming is not always more environmentally efficient than conventional farming. The environmental advantage of organic farming is lost at a high level of nitrogen use. This phenomenon was particularly significant during the expansion period of the NRR experiment in the village. According to the estimates, farmers' uncertainty and lack of training were the principle explanation. With these results, we warn against the excessive expansion of organic farming and urge more prudence. Effective technical supports and strict nutrient regulation are necessary to ensure the sustainability of organic farming development.

Chapter 4 focuses on the farmer education approach of the NRR. We continue to explore smallholder farmers' economic and environmental performance by means of social learning, a participatory education approach advocated in the NRR experiment. In our case, the social learning is organized on basis of Sancha village's social structure and paddy fields location. After carefully defining the learning group, we identify the social learning effect within the reference group using a Spatial Autoregressive (SAR) model. Particularly, we use the technical efficiency (TE) and environmental efficiency (EE) calculated in chapter 3 as dependent variables of the model. The efficiency terms measure farmers' managerial performance which is relevant to the social learning process. It also allows to disentangle the social learning effect from inputs related contamination effect and environment correlated effects. Further, to investigate constraints on social learning, we take into consideration of the technology heterogeneity, i.e. organic and conventional farming, in our estimation.

The estimation results suggest that the effect of social learning is weak due to the technological heterogeneity in the village. For organized organic farming, social learning is significant. Also, female groups are more likely to demonstrate improvement in farmers' performance. In our case, these results have justified the efficiency of NRR education approach in fostering smallholder farmers' performance in our case. However, it appears that farmers learn to improve their economic performance (i.e. maximize yield) rather than environmental performance (i.e. minimize environmentally detrimental input). These results reveal a critical limitation of social learning, and demand more environmental orientation in NRR participatory education and training. Alternatively, the agricultural extension service ensured by the government is expected to guide smallholder farmers and foster their environmental performance for sustainable agricultural development.

This thesis attempts to demonstrate a comprehensive example of an NRR with three in-depth case studies in the village of Sancha in south west China. Our survey and empirical studies suggest that institutional innovation is as important as technology innovation in China's sustainable agricultural development. Along with the rapid development of new agricultural technology, social organisation and human development in poor rural places are essential to achieve the goal of increasing agricultural sustainability. With this common objective, the NRR movement is indeed complementary to the government's nationwide policy, and its experience should inspire ongoing agricultural and rural reform. In a state-civil society partnership, the alternative NRR movement can make a more significant contribution to the development of sustainable agriculture in China.

Chapter 1

The Rural Reconstruction Movement in China

1.1 Historical origins of rural reconstruction

1.1.1 Context of rural reconstruction of the 1920s-1930s

"Rural Reconstruction" is nothing new in Chinese history. This idea and practice date back to the 1920s-1930s. During the 1930s, the world economy was suffering from the Great Depression. Being open to the world market, China was also affected by this deep economic crisis. Driven by economic panic and military power struggles, the importation of staple foods was supported by China's republican government. In 1933, the government signed a loan contract with the United States to import cotton and wheat valued at 50 million US dollars (Chen, 2007). This substantial agricultural importation distorted the market price, whilst production costs were soaring due to heavy land rent and taxes which threatened to bankrupt smallholder farmers. Under China's private land regime, the agricultural land was highly polarized. According to a survey conducted by the republican government in 1933, more than half of the agricultural land was owned by landlords in Henan province. Most rural Chinese were landless or had only a small piece of land. Smallholder farmers were trapped in extreme poverty and expelled from agriculture. The exodus of millions of farmers was observed in years of natural disaster (Rural Revival Committee, 1934).

The declining agriculture and rural economy caused severe social unrest in the countryside and ultimately the dissolution of Chinese society. In this context, intellectuals and reformers turned their attention to the countryside and initiated the first wave of the "Rural Reconstruction" movement in order to experiment with various rural development models. During the 1930s, about 1,000 rural experiments had been launched by 600 social groups. Regarded as a social reform movement, many of these projects adopted an approach of mass education and cultural reconstruction, and some relied on industrial development and military organization to reinforce rural society[1]. Among others, two of the most influential experiments were conducted by “the last Confucian” Liang Shuming and “the father of mass education” Yangchu James Yen (Yan Yangchu) (Zhang and Xu, 1935; Fairbank et al., 1986).

1.1.2 Liang Shuming and his rural experiment

Liang Shuming was a cultural conservative with a strong belief in traditional Chinese values (i.e. Buddhism, Confucianism and Taoism). He believed that the root of traditional Chinese culture is alive in the villages, where cultural renaissance is possible. Being open to new science, Liang aimed to combine traditional Chinese culture and modern technology to revive rural society and further Chinese society as a whole. Under the support of local officers, Liang firstly funded the Research Institute of Rural Reconstruction in Zouping county of Shandong province to train social activists with his theories. Then he translated rural reform with respect to rural education and agricultural development across the county.

Improving education in the countryside and reviving the social ethics and culture of peasants were key to Liang’s reform. To this end, the Research Institute trained thousands of rural educators to settle down in villages and established rural schools at town and village levels. During 1933–1937, 4 township schools and 285 village schools were established in the county of Zouping so that mass education reached almost all people. Within these rural schools, peasants received traditional culture and ethics education. Modern agricultural technologies and new plants were also introduced. Via field experiments, new plant varieties were hybridized with local varieties and were adapted to local conditions. Meanwhile, local knowledge was revived and diffused through rural schools. By way of mass education and agricultural development, the villages realized self administration and economic independence.

Liang stressed the importance of farmers’ cooperation for rural economic development. Originally, farmer cooperatives were introduced and employed to unite smallholder farmers. For instance, the first cooperative established by Liang was the cotton production cooperative in Huopo village. Farmers received improved cotton seeds and technical guidance from the cooperative, and their product was collected and packaged by the cooperative and sold directly to spinning mills. To overcome capital constraints, farmers could get loans from the bank with the guaranty of the cooperative. After 2 years’ development, the area of cotton fields increased from 900 mu (60 ha) to 40,000 mu (2,667 ha) in the village. In addition to the cotton cooperative, 307 other cooperatives were created successively with specialization in silk production, forest organization, credit loaning, product stock and marketing. Approximately 10 thousand rural households were incorporated in Zouping county.

Apart from education and economic development, Liang also restructured local government and streamlined staff, constructed irrigation facilities, improved health care quality, and orga-

[1]Among others, Liang Shuming, Yangchu James Yen, Tao Xingzhi, Lu Zuofu and Peng Yuting were representative practitioners of the movement.

nized farmers for military defense. These comprehensive reforms made the Zouping experiment the most successful one in the Rural Reconstruction movement. Unfortunately, this experiment was disrupted by the Sino-Japanese War and abandoned in 1937 (Alitto, 1986; Liang, 1992).

1.1.3 The mass education of James Yen

Unlike Liang Shuming, James Yen had an overseas background. He received higher education in the United States and subsequently worked in France. Yen was a liberal and a Christian who served in the church. With a different ideology than Liang's Neo-Confucianism, Yen found that the core problem of Chinese society was in the people. To revive the country, he believed, one should firstly empower the people through education. Therefore, he argued, the social reform should begin in the countryside where most Chinese people lived (Yen, 1989; Hayford, 1990). In 1929, Yen settled in Ding county of Hebei province to start his experiment of mass education and attracted 500 social activists and scholars from around the world. Based on in-depth and precise field investigation, Yen summarized China's rural problems as peasants' ignorance, poverty, illness and selfishness. The remedy to these problems thus relied on mass education with respect to culture, livelihood, health care and civic mindedness.

In terms of cultural education, Yen and his colleagues committed to reduce the illiteracy rate in the countryside and teach farmers science and new technologies. They edited and published the "farmers' newspaper" and established a farmers' radio and performance group to promote local literature, art and theater. In terms of livelihood education, they adopted the same approach as Liang to establish farmer cooperatives. Pilot farmers were trained to experiment with new agricultural technology and new varieties of cotton, poultry and pigs. Then successful techniques and products were diffused by pilot farmers in the cooperatives. By 1935, more than 130 cooperatives had been founded in the county. A new health care system was established with local healthcare workers at the village level, care houses at the district level and hospitals at the county level. Consequently, peasants had easy access to health care and vaccines, and a number of epidemic diseases (e.g. Smallpox, Cholera, Meningitis, Scarlet fever) were under effective control in the county. In terms of civic education, peasants were trained to provide public services. In Gaotou village, Yen founded the villager autonomy office where peasants were allowed to discuss collective issues such as village convention, road building and land surveillance.

Yen's experiment in Ding county had lasted for 8 years until it was disrupted by the Sino-Japanese War in 1937. However, Yen pursued his rural reconstruction experiments in Sichuan, Hunan and in Chongqing, where he founded the Institute of Chinese Rural Construction. From 1950 until his death in 1990, Yen promoted his initiatives to other developing countries in Asia, Africa and Latin America. In recent years, the International Institute of Rural Reconstruction in the Philippines, which was founded by Yen in 1960, has become a vibrant laboratory of sustainable agriculture and democracy training (Yen, 1989; Sun, 2006).

1.2 New rural reconstruction movement in contemporary China

Today, war in China has ended, and the political environment and socio-economic conditions have changed. However, rural problems persist. In addition to the classic social and economic destruction of the past, China's rural problems have taken new forms.

1.2.1 "Three Dimensional Rural Problems" and New Rural Reconstruction

In the planed economy era, the Chinese Communist Party (CCP) government used the "Price Scissors" to extract agricultural surplus from the countryside under industry-oriented development strategy[2]. It is estimated that 1,500 billion Yuan flowed out of the countryside between 1979 and 1994, which partially explains the stagnation of the rural economy in recent years (Zhang et al., 1996; Lin and Yu, 2008).

Since the 1990s, the reform of the food procurement system has improved the situation, but food prices are always monitored by the government and maintained at a low level. In addition, the growing rural population and fragmentation of agricultural land have atomized agriculture over time. Therefore, smallholder farmers have little power in bargaining with wholesalers on the market. Yet the costs of production continue to increase steadily. Despite government subsidizes on inputs, the excessive use of fertilizers weighs heavy for smallholder farmers. The cost of rice fertilizers, for example, is estimated to 20 billion Yuan/year and could at least double over the next 30 years (Norse et al., 2001). Consequently, agriculture has become so unprofitable that more and more farmers are abandoning their land and quitting agriculture.

By contrast, the manufacturing sector is booming in the cities and increasing the income disparity between urban and rural residents. The Gini coefficient has increased from 0.21 to 0.47 over the past 30 years (NBSC, 2011). Due to the expansion of the urban economy and urbanization, the demand for land is increasing and land grabs are becoming frequent. In case of land confiscation, weak farmers receive arbitrary and well below market price compensation. According to Ministry of Construction statistics, the numbers of petitions over land confiscations have substantively increased since 2003. It is estimated that about 40–50 million farmers have lost their land in the urbanisation process (CASS, 2011).

The recession of the rural economy and land grabs accelerate the phenomenon of China's rural exodus. In 2011, the number of "peasant workers" reached 252.78 million, of which 158.63 million migrate and work in the city (NBSC, 2011). This tremendous rural exodus has increased farmers' off-farm income and improved their welfare but also has had an adverse impact on agriculture. As most "peasant workers" are male and young farmers, the available labor force for agriculture production is declining. Some estimates suggest that the rural labour surplus

[2] The "Price Scissors" denotes the domestic terms of trade between agriculture and industry.

was less than 120 million in 2005, and that about 50% of this labor are over 40 years old (Cai, 2007; Cai and Wang, 2008). Along with the outflow of rural labor, village hollowing is becoming a common phenomenon. During 2000 and 2010, 0.9 million natural villages with their rich cultural heritage quietly disappeared .

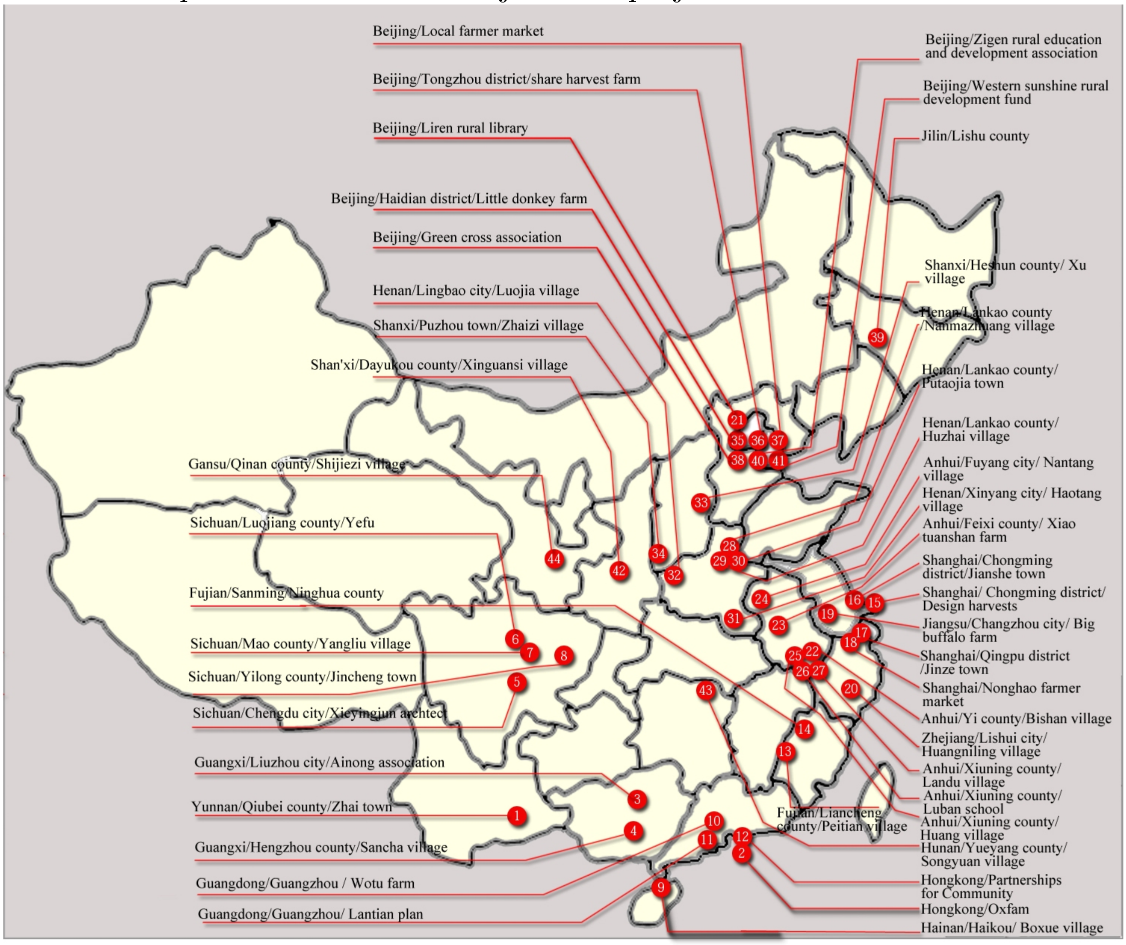
These critical problems are summarized as the "Three Dimensional Rural Problems"(*San nong wenti*) by Wen Tiejun, the main advocate of rural reconstruction in contemporary China. In Wen's opinion, The "Three Dimensional Rural Problem" can not be solved if it is treated as a single agricultural economics issue and left to the market. The current "modernization" of agriculture is not a panacea to all problems. Wen argues that to find the real solution, one needs to explore a more peasantry-focused and community-based rural development model (Wen, 2007).

In order to translate his theory into action, Wen founded the James Yen Rural Reconstruction Institute in Ding county of Hebei province in 2003[3]. In 2004, Wen founded the Liang Shuming Rural Reconstruction Center in Beijing. The next year, he founded the Rural Reconstruction Centre at Renmin University of China. On the basis of these networks, students, intellectuals and social activists have once again united to form the "New Rural Reconstruction" (NRR) movement and to conduct social experiments in rural areas across China.

There are no official statistics about the NRR movement given its grassroots nature and loose organisation involving thousands of people and hundreds of independent organizations (e.g. NGOs, peasant organizations, academic institutions, student groups, "social enterprises" and a few state agencies). Since 2006, the government has launched a broad rural development campaign entitled the "Socialist New Countryside Construction" (*Shehui zhuyi xin nongcun jianshe*). Some NRR projects prefer framing their position under the government policy. According to the data shared within the network of Liang Shuming Rural Reconstruction Center, a map of distinct NRR projects is drawn to show the distribution of the NRR in mainland China (see Map 1).

[3]The James Yen Rural Reconstruction Institute was shut down by local government in 2007.

Map 1. Distribution of major NRR projects in mainland China



Source: sumarize of Zuo Jing and Ou Ning

1.2.2 Some examples of New Rural Reconstruction

Just as in the republican era, the actual NRR movement takes various forms. Most of the experiments draw ideas and inspiration from China's historical experiences to focus on rural social and cultural reconstruction and comprehensive farmer cooperative building. To address the new problems of agricultural pollution and food safety, smallholder organic farming and alternative agro-food networks are being developed and promoted on many experimental sites. The new objective of the current NRR movement is thus to achieve sustainable rural development in declining rural economy.

Several examples are often cited to represent the NRR movement. One of the most famous examples is the "Nanmazhuang" experiment conducted by He huili in Lankao county of Henan province[4]. The experiment got started in the village of Nanmazhuang in 2003. To address the "cultural poverty" and atomization problems in the village, a dance troupe and a senior association were firstly organized to revive local culture and boost farmers' spirit of cooperation. On the basis of these cultural organizations, the "Nanmazhuang" cooperative was founded in 2004.

[4] He huili is a doctor of law from Beijing University. She is a student of Wen tiejun.

In contrast to a "specialized cooperative", the "Nanmazhuang" cooperative is multi-functional and comprehensive. Apart from ecological rice production, the cooperative popularized the integrated "crab–lotus" agro-system and mushroom production. In addition, traditional pig and poultry farming (i.e. the smallholder and organic method) was introduced to provide organic fertilizer for rice production. As such, various components of the cooperative are interdependent and support each other. To overcome capital constraints, a credit mutual aid group was also created within the cooperative. This comprehensiveness makes the cooperative more of a process than a static form and allows it to develop along with the rural community. For the experiment diffusion, He has now established 5 folk troupes and 4 comprehensive cooperatives in 6 villages of Lankao county.

Among the challenges, He notes marketing as the biggest in the "Nanmazhuang" experiment. In niche markets, farmers have encountered great difficulty selling their ecological products. Without high economic compensation, they are reluctant for conversion to labor intensive and "risky" ecological agriculture. Furthermore, the organization of farmers has great political risk and little financial support. Potential conflicts with local government and the ambiguity of law on farmer financial organizations are obstacles for the experiment's further development.

Another interesting NRR experiment is the Bishan project with its particular emphasis on the role of art and culture in rural areas. In 2011, the visit of Zuo jing and Ou ning to Bishan village in Anhui province gave birth to a "Utopian" project of Bishan commune[5]. At the beginning, they invited artists, architects, designers, musicians, film directors, writers and student volunteers from around China to explore the heritage of Bishan village and observe the local culture. Based on this investigation, they began planning for the first Bishan Harvestival in collaboration with local farmers[6]. Festival activities centered on the presentation of village history, protection and revitalization of housing, design of traditional crafts, staging of traditional opera and musical performances. Meanwhile, the festival was also a forum where NRR social activists could discuss and share their experiences.

The successful Harvestival has received local government's attention and support. In 2012, the second Bishan Harvestival was integrated into the government's Photo Festival, which invited worldwide artists to focus on themes of environmental protection, community supported agriculture, rural economic cooperatives and community colleges. Using art and culture as a focal point, the Bishan experiment attempts to incorporate farmers in modern art production and local culture conservation. By revalorizing local culture and traditional handicraft with modern design, they hope to boost rural economy and establish a more equitable relationship between city and countryside. Despite being criticized as too idealist and being constrained by financing problems, the Bishan project continues its experiment and struggle.

Finally, the "Little Donkey" project is a prominent experiment of Community Supported Agriculture (CSA) in China. In 2008, the "Little Donkey" farm grew out of the concept of

[5] Zuo jing is an associate professor at Anhui University. Ou ning is a independent artist.
[6] Harvestival is a festival to celebrate the annual harvest.

community-based sustainable living. It was founded by Shi yan and her collegues in the periphery of Beijing as the first CSA farm in China[7]. The small farm was only 230 mu (15 hectares) but was designed as a multi-functional base for community involvement through visits or public land rentals, ecological agriculture demonstrations, training and education, technology research and development, as well as theoretical research and policy advocacy.

The "Little Donkey" farm boasts a core research base through affiliation with the Institute of Rural Reconstruction to generate successful experiences of organic farming, permaculture and integrated agro-ecological system, which are then promoted to other NRR projects. It has also introduced and adapted the CSA business model to the Chinese case. Its ecological agriculture practices have convinced consumers and attracted them for direct marketing. By organizing lessons and workshops, the farm seeks to increase consumers' awareness on issues surrounding food, environment and sustainable livelihoods. As such, it mobilizes not just farmers, but citizens, and governments to join the sustainable agricultural movement. So far, the experience of "Little Donkey" farm has been diffused widely and influenced hundreds of CSA farms across the country.

Three examples can certainly not comprehensively illustrate the NRR movement in China. More meaningful and location specific experiments such as projects of He xuefeng in Hubei, Li changping in Henan, Liao xiaoyi in Sichuan, Qiu jiansheng in Hainan and Fujian should be mentioned. The realm of the NRR has extended to rural-urban coordination, eco-village and tourism, rural democracy and migrant right defense, which are far beyond the scope of my research. In order to provide deep and comprehensive understanding about the potential of the NRR in sustainable agricultural development, we only focus on the NRR's agricultural component in this thesis. We have identified a recent NRR experiment and conducted a six-month field research in a remote village, to which we now turn.

[7] Doctorate in agricultural economics of Renmin University, Shi yan is also a student of Wen tiejun.

1.3 Field research in Guangxi province

Map 2. Location of research field

Note: Map compiled by author

The field research was carried out in Guangxi Zhuang Autonomous Region in the southwest of China (Map 2). Guangxi is a region characterized by the mountainous topography and the ethnic diversity. In spite of minor proportion in the total population (i.e. less than 9%), ethnic minorities are widely represent in the south west and north of China. Zhuang people are the largest ethnic group that mainly reside in Guangxi province. Other ethnic minorities such as Miao and Yao and Dong are also present in this region. Due to the cultural barriers, capital and market constraints, ethnic minorities represent a large share of rural poor and constitute the majority of food insecure population in China. With this social composition, Guangxi is recognized as one of the poorest provinces in China. In 2010, the Gross National Product (GDP) of Guangxi was 957 billion yuan, which represented only 2% of the national GDP. Agriculture is an important sector in Guangxi, which represented 28% of the total economy (NBSC, 2011). The traditional agriculture is in transition to modern agriculture in Guangxi. Since the 1960s, the use of modern inputs and high yield hybrid varieties have been popularized across the region. The chemical fertilizers application rate in Guangxi was 26kg/mu, which is higher than the average rate of 23kg/mu in China (NBSC, 2011). The agricultural pollution and environmental protection are becoming concerns of the local government and have attracted research interests in recent years.

1.3.1 Precedent research

In 2000, a research project was initiated by the Center for Chinese Agricultural Policy (CCAP) in 11 villages in Guangxi region (Song et al., 2010). The CCAP research investigates the synergies of local farmers' participatory agricultural research with formal agricultural research system, with a focus on the maize production. The major findings of CCAP research highlight the potential of local farmers' cooperation in plant breeding, seed variety selection and management and local knowledge revival for sustainable agricultural development in Guangxi (Vernooy, 2003; Vernooy and Song, 2004; Song, 2003). By following the CCAP research, I was interested in one village called Sancha, which was identified by a Hong Kong based NGO called Partnerships for Community Development (PCD) as experiment site for the NRR and sustainable agricultural development in 2005[8]. In collaboration with the NGO and the Guangxi Maize Research Institute (GMRI), I decided to conduct a field research in this village[9].

1.3.2 Socio-economic condition of Sancha village

Sancha village (109.01E/22.73N) is a natural village[10] in the northwest of Pingma town of Hengzhou county[11]. The village is in a mountainous zone located 4 kilometers away from the town and 30 kilometers away from the county center. Given its remote location and rich forest resources, the village is classified in a protected ecological zone. As a result, the arable land is scarce, only 360 mu (24 hectare) for about 120 households of the village. In the 1980s, the Household Responsibility System (HRS) was implemented in the village, which turned the collective farming system into an independent smallholder production system.

The social structure of Sancha village is divided given its mixed ethnicity (Zhuang, Han, Miao and Yao). Originally, there are four families (Li, Xu, Huang and Lu families) based on ethnicity and the kinships. For instance, most of the Xu family are Zhuang people, whilst most of the Huang family are Han people. The ethnic minority people have their own languages and culture. They continue to transfer their language and culture to future generations within their family. Nowadays, young people can also learn Mandarin when they go to school. But older people of the minority families only speak their own language. As such, the culture and language diversity render farmers' communication very limited in the village.

Given the remoteness, land scarcity and smallholder production, economic development in Sancha village is quite slow. According to the village head, the average revenue was only 1,700 yuan per capita in 2007. The village is recognized as a provincial "Poor Village" in Guangxi. In terms of agricultural production, paddy rice is the main crop in the village given its abun-

[8]The PCD is engaged in the networks of Institute of Rural Reconstruction. For more details about the NGO, please visit their website: www.pcd.org.hk.

[9]GMRI is an agronomic research institute sponsored by local government.

[10]A village in China can either be a natural village (ziran cun), one that spontaneously and naturally exists, or an administrative village (xingzheng cun), which is a bureaucratic entity.

[11]There are five levels of administration in China from high to low: province, city, county, town and village. Governments are present at 4 levels except for the village level.

dant mountain spring water and tropical climate. Most of the production are for subsistence consumption, whilst a small surplus is sold on local market. In recent years, cash crops such as sweet corn and mulberry are introduced to improve the rural economy. Farmers raise chicken and duck, some also raise pigs in a traditional way, mainly for self-consumption. Trade fairs are organized every three days in the town, farmers sell their surplus produce and buy life necessities on fairs. In 2008, Sancha village was identified for the "Socialist New Countryside Construction". It thus received funds from the local government for its infrastructure construction, e.g. a cement road linking the village to the town, a floodlit basketball court and a portable water project.

Sancha village was also identified by the PCD for a project of organic rice production in 2005. At the beginning, experiments were introduced to the Li family. In collaboration with the GMRI and the CCAP, the PCD employed initiatives such as technical training, environmental education and marketing support (CSA) to encourage farmers' conversion from conventional farming to organic farming. Local knowledge was revived by means of farmers' participatory research. For instance, various formulas of composting, the "Duck-Rice" system and traditional medicinal plants were discovered to substitute chemical inputs. After three years' experiment, the project was evaluated and considered as successful. In 2008, the project was extended to the whole village. At the end of 2009, 78 households were engaged in organic farming and the total organic areas reached 66 mu (about 20% of total cultivated land in the village).

1.4 Survey methods and data

Sponsored by the *foundation of University of Auvergne* (UDA), I was able to design and conduct surveys in Sancha village to collect micro level data for empirical analysis of the NRR. The survey project begun in 2010. On the basis of information collected by telephone interviews with the PCD coordinator, a semi-structured questionnaire was designed. A field inspection was then conducted in collaboration with the PCD and the GMRI. The questionnaire was tested with key informants (i.e. the village head, the party secretary, the GMRI agronomist and the PCD coordinator) as well as a sample of randomly selected households (10%) in the village between April and May 2010[12]. Through the field inspection and investigation, a number of data source was identified. For instance, the PCD had records of farmer who engaged in the organic farming since 2005[13]. The GMRI agronomist also recorded experimental data of paddy rice production in the village (e.g. nitrogen content of inputs and output). In order to collect complementary data for our research purpose, a census of all households in Sancha village was implemented given the small area of Sancha village and farmers' availability[14].

[12]A stratified sampling method was applied to take account the disproportioned organic and conventional farmers in the villages.

[13]See an example of the PCD's record in Appendices.

[14]The survey was implemented by the author with assistance from the PCD coordinator and an interpreter in the village.

The formal survey was organized in two rounds with different focus. The first round focused on the NRR was implemented between June-August 2010 (see questionnaire I in Appendices). All households identified by the pretest were visited and a face-to-face interview with household head took place at their home. During about one hour, questions about household's practice of organic farming, perception and participation in the NRR as well as household's socio-economic characteristics were asked. With the regret of a true panel data, recalled information of 2008 and 2009 was collected by the survey (i.e. retrospective panel). In order to ensure the data's accuracy, households' answers were carefully checked with historical records of the PCD so that any suspicious answers were rejected. After data cleaning, a sample of 108 households for two years was retained[15] and the response rate of the survey attained 90%[16].

The second round was implemented between September-October 2010. The former 108 households surveyed in the first round were revisited, and 102 revisits were successful[17]. The second round investigated smallholder paddy rice production (see questionnaire II in the Appendices). All paddy fields of the 102 households were identified and located[18]. Among these fields, one organic field and one conventional field were randomly selected for the survey. In the case of non-organic households, two conventional fields were selected and *vise versa* for totally organic households. The interview took place in the paddy field with the household head. Questions about the inputs (labor, capital and fertilizers which were identified by the pretest) and outputs of rice production (raw rice), agricultural technologies (e.g. organic farming or conventional farming) were asked to the end of the production function analysis. In addition, geographical environment and characteristics of the field were recorded as well. Information was collected according to different crop seasons[19]. After data cleaning, a retrospective panel of 203 plots for five seasons (i.e. from 2008 to 2010) was derived.

Based on these data, we can derive more precise information of Sancha village and discuss preliminary understanding about the NRR in the village. According to the survey data, Sancha is a representative of southern villages. Households are mainly headed by aged (54 years old on average) and female farmers (61% of households with female head). Specifically, 80% of households belong to ethnic minorities. Most households practice smallholder agriculture (paddy field is about 2 mu per household) in a traditional way, e.g. 77% of households raise cattle for agricultural production, whilst only 9% of households possess a tractor. In terms of revenue, the largest part consists of non-farm income and remittance from relatives who work in the city. However, agricultural production was growing. For instance, agricultural revenue increased from 35% to 48% between 2008 and 2009 (see Figure 1 for more details).

[15] The sample is composed of 26 households of Xu family, 28 households of Li family, 27 households of Huang family and 27 households of Lu family.

[16] The response rate is reported according to the definition and calculation of the American Association for Public Opinion Research (AAPOR, 2011).

[17] For the six lost households, one was deceased, one was hospitalized and four migrated.

[18] In general case, a household has three to five plots.

[19] The rice is produced twice per year in Sancha village. The inputs and output vary according to the climate of the season.

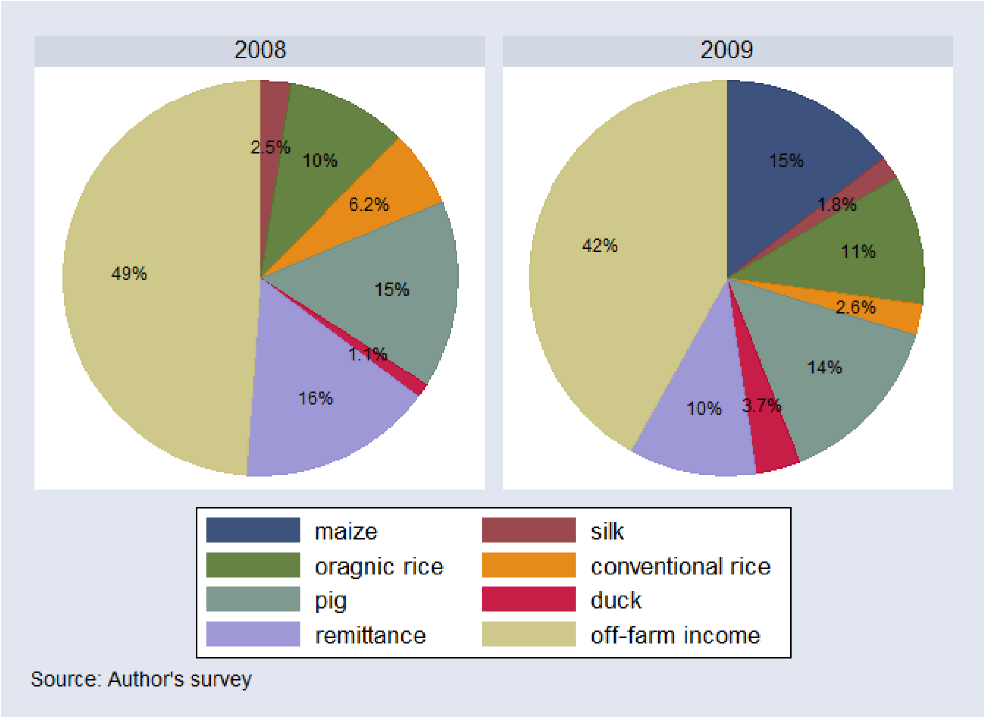


Figure 1. Agricultural revenue and off-farm income in Sancha village

Particularly, organic rice production (generated about 10% of the total revenue) was growing rapidly. As one can note in Figure 2, the areas, output and revenue of organic farming increased significantly between 2008 and 2009. We also note that the development was heterogenous among four families. For instance, the Li family is ahead of other families in organic farming, whilst the Lu family got started from zero and demonstrated the fastest growth rate. Intuitively, the development of organic farming went hand in hand with the NRR development which suggests a positive impact of the NRR on sustainable agricultural development in the village.

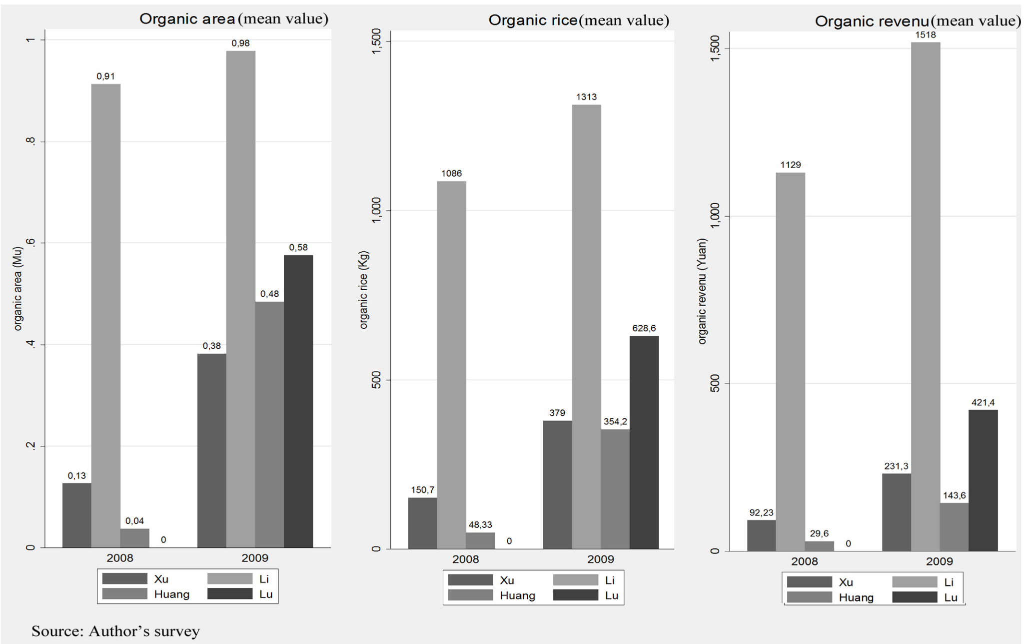


Figure 2. Organic farming development in Sancha village

In summary, the field work in Sancha village is a starting point of our study. Through the conversations with key informants and farmers, we gathered accurate background information and discovered story of the NRR. By means of the field work, we identified available historical records and precise agronomic experiment data. More importantly, household level and plot level data were collected using household survey method. In the following chapters, we will explore this dataset to provide three in-depth case studies. We aim to illustrate how NRR works in Sancha village and have a discussion about the potential of this bottom-up movement for sustainable agricultural development in China.

Chapter 2

Case I: Social Reconstruction and Collective Action for Sustainable Agricultural Development*

2.1 Introduction

For many countries in development and transition, the need for sustainable agricultural development is acknowledged as a common consensus among policymakers. However, how to achieve this goal remains questionable. In China, the critical "Three Dimensional Rural Problems" (*Sannong wenti*) has opened the question to various attempts for adequate solutions. In contrast to the mainstream technical model (i.e. agricultural industrialisation and technology innovation), alternative thinking stresses institutional innovation for sustainable agricultural development (i.e. smallholder peasants' collective action and cooperation) (Ostrom, 2000; Berkes et al., 2002; Wen, 2007). In practice, a grass-roots movement of the "New Rural Reconstruction (*xin xiangcun chongjian*)" henceforth "NRR" has emerged to promote community-based and peasant-centered agricultural development in China since 2003.

The NRR is an ongoing rural development movement involving hundreds of thousands of scholars, students, social activists and development agencies in China. Across the country, most NRR initiatives consist of first constructing social and cultural organisation (e.g. women and senior associations), then developing comprehensive co-operatives for the sake of economic and agricultural development[1]. NRR practitioners advocate that social and cultural reconstruction is of primary urgency in atomized Chinese rural society[2]. In order to achieve sustainable rural development, one should firstly construct a solid social basis for cooperation among smallholder

*This chapter is an adapted version of an article submitted to *The Journal of Development Studies*.

[1]One can refer to Lishu county co-op in Jilin, Lankao county co-op in Henan and Jiangzhuang co-op in Shandong, for example (Day, 2008).

[2]The atomization of rural society is the extreme of decollectivization since the 1980s.

farmers. To this end, social and cultural activities are appropriate and cost-effective means to unite smallholder farmers and to empower them through the spirit of cooperation.

After ten years of development, the NRR movement is beginning to attract academic interest. Some scholars have recently studied the economic aspect of the NRR and regard it as the emergence of the new social economy in China (Pan and Du, 2011a,b). However, the effectiveness and efficiency of NRR approach have never been tested in economics and little is known about its social mechanism. This chapter attempts to fill in this blank in the literature and to provide a deeper understanding of the NRR and its impact. Beyond the empirical test of the relationship between social reconstruction and sustainable agricultural development, the aim of the chapter is to investigate the social mechanism underlying this relationship. Our study is essentially inspired and guided by the literature of social network economics, a thriving literature emerging in economics that explores the influence of complex social interaction on economic achievement (Manski, 1993; Brock and Durlauf, 2000; Moffitt and Valente, 2001; Durlauf and Fafchamps, 2003; Lee, 2007; Bramoullé et al., 2009; De Giorgi et al., 2010). Our study will also make a contribution to this literature by providing micro evidence in the domain of agricultural development.

Considering the lack of macro data, an in-depth case study is appropriate in order to derive a deeper understanding of the NRR. We identify an original NRR example in a village of southwest China where basketball matches have been organised to unite smallholder farmers in organic farming development. With a rural household survey, we investigate farmers' motivation for adopting organic farming and the influence of the basketball matches on their social networks. This qualitative study derives a key hypothesis of social network extension via basketball matches in the village. We model the social network according to this hypothesis and then identify the social network effect on farmers' adoption of organic farming using data collected by the household survey. In terms of econometric methodology, we follow the discussion of Moffitt and Valente (2001) in regards to policy intervention and identification of the social network effect. Our identification stems from the exogenous change of social network due to policy intervention (i.e. basketball matches). In practice, we make use of the Heckman correction for the endogenous formation of social networks and rely on the exclusion restriction of the Inverse Mills Ratio to construct instruments for endogenous social network effect. This novel Heckman-IV approach also finds application in other studies of social network effect (Zeitlin, 2009; Patnam, 2011).

For the results, we identify a significant and robust social multiplier effect on the diffusion of organic farming, which confirms the effectiveness and efficiency of basketball matches. Moreover, we identify women, education and labor as determinant factors for organic farming development in rural China. Our result highlights the constraints of social activity in large villages and provides guidance for rural project design in similar circumstances. Finally, we conclude that social networking by way of social and cultural activities is crucial in promoting sustainable agricultural development in small villages.

For the rest of the chapter, Section 2 presents the NRR case study; Section 3 provides details of our fieldwork; Section 4 describes the dataset; Section 5 explains the methodological and econometric issues; Section 6 discusses the main results and policy implications; Section 7 concludes.

2.2 Social reconstruction and organic farming development

Among divers NRR experiments across China, we were interested in an original example from southwest China. Sancha village is a small ethnically mixed village (a mixture of Zhuang, Miao, Yao minorities and Han people) with 120 permanent households under the administration of Pingma town in Guangxi Zhuang autonomous region (see Chapter 1 for the location of Sancha village). Traditionally, the social life and agricultural production in the village are organized on the basis of four families (i.e. families Xu, Li, Huang and Lu, also labeled as production groups 1, 2, 3 and 4). Since the 1980s, the implementation of the Household Responsibility System (HRS) has broken the collective system into a system of individual production (Lin, 1997). As such, the cooperation among farmers has been weakened and the communication between families is constrained by different languages and culture.

Given its underdeveloped state and well-preserved agricultural environment, Sancha village was targeted in 2005 as an NRR experimental site for sustainable agricultural development by an NGO called PCD. Initially, a project of organic paddy rice production was introduced for experimentation to family Li of the village. During this early stage, PCD, in collaboration with Guangxi Maize Research Institute (GMRI), provided environmental education, technical training and marketing support (by Community Supported Agriculture) to encourage farmers' conversion from conventional farming to organic farming. After three years of experimentation, diverse organic technologies (e.g. substitution of chemical fertilizers by organic compost, a rice-duck integrated system and insect control by medicinal plants) were successfully adapted to local conditions and judged as successful. The adoption rate reached 90% within the Li family in 2008.

However, the project's ambition reached beyond success within a single family. PCD aimed to promote successful organic farming to the whole village, which was not a simple task. According to PCD's investigation, farmers of other families doubted the yield of organic farming, due to lack of information. As a result of the communication barrier among families, farmers had no access to complete information about organic farming gained by the Li family. After one year's campaign of promotion by PCD, the adoption rate was only 29% for the whole village in 2008.

Fortunately, the situation was changed by an intervention of the local government. For the sake of urban-rural integration, the local government decided to incorporate Sancha village into the Pingma community[3]. As a result, Sancha village received a government grant for its

[3]The term of community is employed to align the rural village with the urban district in the policy of rural

community building. With this grant, an old elementary school playground was transformed into a floodlit basketball court at the end of 2008.

In a poor village like Sancha, the new court represented modernity for inhabitants and evoked great basketball enthusiasm. After realizing this basketball model, the village committee decided to organize regular basketball matches with support from the PCD. A basketball league was organized by inviting neighbor village teams to play matches on the new court. For pragmatic considerations, the basketball matches were generally scheduled in the evening, as farmers would have more spare time in the evening and more spectators could be present. Moreover, the scheduling of school children was considered as well. Still, the risk that mountainous environment conditions and lack of road light might constrain some farmers from attending the matches in the evening should be noted[4]. Thanks to the basketball league, the social life in Sancha village was substantially enriched, according to the village committee. More importantly, the barrier of the four families was broken down, and more intensified social interactions encouraged farmer cohesion. For instance, in 2009, the village won the league match against seven neighbor villages. The prize of a black pig was shared equally by the four families.

Surprisingly, PCD found that the organic farming project also moved forward along with the basketball league. Farmers' knowledge about organic farming increased considerably. At the end of 2009, the adoption rate reported by farmers reached 73% for the whole village.

2.3 The survey and research intuition

In order to understand the story of the basketball matches, we decided to conduct a survey in the village. The aim of our fieldwork was to investigate: 1) the motivation of smallholder farmers to adopt organic farming; 2) the role of the basketball matches in the promotion of organic farming; 3) the evolution of social networks in the village. A semi-structured questionnaire was designed according to information gathered on the Internet and by telephone interviews with project field coordinators. To make our questionnaire relevant to the context and to gather more background information, we began with a preliminary interview of key informants (the head of the village, party secretary and PCD project coordinator) as well as a sample of 15 randomly selected households in the village (10 organic farmers and 5 non-organic farmers, which represent about 10% of the population).

All interviews took place at farmer's homes over dinner and the conversation unfolded in a friendly atmosphere. According to these interviews, three main motivations for organic farming were identified: 1) health considerations 2) economic profit and 3) access to information. Firstly, concerns about health risks were put forward by most farmers who practice organic farming (9 of 10 respondents). Six of them confirmed that diseases related to spray of toxic chemical

community construction announced by Chinese Ministry of Civil Affairs.

[4] This particular condition is important for our identification strategy. We will discuss it in detail in the section on methodology.

pesticides (e.g., dizziness, vomit and dermatitis) are common in the village, which pushed them to adopt organic farming. Secondly, farmers reported that the price premium of organic rice is attractive (7 of 10 respondents). Although organic food represents a niche market in China, the price is about two times that of conventional food[5]. Thirdly, the knowledge of organic farming strongly correlated with farmers' adoption. For instance, organic experts of the Li family, who had engaged in PCD's experiment, had comprehensive information about organic farming and were familiar with all organic technologies. They were generally confident about the productivity of organic farming and supported it firmly. For new organic farmers, most of them regarded organic farming as safe agriculture, but their understanding about comprehensive organic technologies was fuzzy. Non-organic farmers had heard about organic farming but had no comprehensive knowledge. Most of them were worried about yield reduction due to conversion.

We then investigated the source of information about organic farming by asking the question "*Where do you learn about organic farming?*" All of the Li family farmers cited PCD as information provider. However, this was not the case for farmers from other families. Five of them reported that they learned about organic farming from their relatives, neighbors and friends. This answer was confirmed by the coordinator of PCD, stating that the NGO had tried to promote organic farming to all farmers, but many of them were still out of reach. Curiously, three farmers mentioned that they learned about organic farming on the occasion of a basketball match. As one farmer reported: "*I get to understand organic farming for the first time after the conversation with Li bing*[6] *in the basketball match.*"

We got the hint and continued to explore the role of the basketball matches. According to our field observation, most farmers of family Li live close to the basketball court. In fact, given their proximity, farmers of family Li have got used to playing basketball and love this sport. Therefore, participation in the basketball matches may have induced more contacts with farmers of family Li. This observation explains how farmers got information about organic farming from the basketball court.

"*So what is the biggest change resulting from the basketball matches?*" To this question, we got different answers. In general, 13 of 15 respondents confirmed that the basketball matches had induced more communication with other farmers. Not surprisingly, when asked to count the friends of other families, farmers who reported to frequently participate in the matches generally counted more than 15 names. In contrast, those who reported to have participated rarely counted less than 5 names. Intuitively, our interviews revealed that farmers' social networks indeed intensified thanks to the basketball matches. This understanding led to a hypothesis to test: the basketball matches promote organic farming in Sancha village by way of social networking.

[5]The price of organic rice is 7 Yuan/kg through the CSA marketing, whereas the price for conventional rice is about 4 Yuan/kg on the local market.

[6]Li bing is a farmer of family Li. The name is fake for the sake of privacy.

To empirically test this hypothesis, we revised our questionnaire with the feedback from the interviews and implemented a census in Sancha village[7]. In practice, the formal survey was implemented in the form of face-to-face interviews with the head of household at home. The formal survey lasted for about one hour. Key question such as "*On average, have you or your family participated in the basketball matches as player or audience more than 3 times per month?*[8]" was asked to measure farmers' participation in the basketball matches. "*Do you practice organic farming on at least one plot of your paddy land?*" and "*Can you tell the difference between organic farming and conventional farming?*" are asked to measure farmers' adoption of organic farming.

In addition, household socio-economic characteristics (e.g. age, gender and education level) and living conditions were also recorded during our home visits. Respondents were asked to recall information for 2008 and 2009. The response rate of our survey was 90%[9]. It should be noted that the data we collected is a retrospective panel data using a single survey. To ensure the accuracy, we checked the answers with available NGO records and dropped information from any non-relevant interviews[10]. After data cleaning, information from 108 households for 2008 and 2009 was retained for the empirical analysis.

2.4 Data

In this section, we describe the dataset derived from the formal survey for our empirical analysis. It contains information about farmers' reporting of participation in the basketball matches and organic farming adoption, as well as key socio-economic characteristics for 108 households during 2008 and 2009[11]. Table 2.1 presents the descriptive statistics of main variables by organic status of household. A summary for the definition of these variables can be found in Tables and figures 4.6.

[7] See an example of questionnaire I in Appendix.

[8] According to the village head, the matches were organized weekly. Therefore, we regard households who report to have participated at least three times per month as frequent participants who are able to make effective social connections with others.

[9] The response rate is reported according to the definition and calculation of the American Association for Public Opinion Research (AAPOR, 2011).

[10] The rejected cases included farmers who were too old to answer the questions, farmers who refused to be interviewed and farmers who don't practice agricultural production.

[11] All interviewed households have actively participated in paddy rice production, using either conventional or organic methods. Some farm in a hybrid manner, using both conventional and organic farming.

Table 2.1: Descriptive statistics by organic adoption status

	Total (216)		Organic (108)		Conventional (108)		t-test
	mean	Sd	mean	sd	mean	sd	p-val
Individual characteristics:							
BASKET(1=Participated)	0.55	(0.50)	0.94	(0.25)	0.17	(0.37)	0.00
AGE(in years)	53.62	(12.82)	54.00	(12.19)	53.24	(13.46)	0.66
SEX(1=woman)	0.61	(0.49)	0.67	(0.47)	0.56	(0.50)	0.09
EDUCATION(in years)	3.63	(3.31)	3.8	(3.52)	3.46	(3.10)	0.46
HOUSEHOLDSIZE(in no.)	3.42	(1.61)	3.49	(1.67)	3.34	(1.56)	0.50
FARMSIZE(in mu)	2.13	(0.95)	2.22	(0.96)	2.05	(0.93)	0.18
INCOME(in Yuan)	1946.00	(5919.65)	2331.02	(7067.62)	1560.97	(4490.14)	0.34
REMOTENESS(walk time)	1.86	(0.70)	1.56	(0.65)	2.16	(0.63)	0.00
KID(in no.)	0.34	(0.61)	0.35	(0.60)	0.32	(0.62)	0.74
Peers' characteristics:							
GORGANIC	0.54	(0.34)	0.79	(0.10)	0.28	(0.30)	0.00
GAGE	53.75	(1.13)	54.18	(0.59)	53.31	(1.34)	0.00
GSEX	0.61	(0.05)	0.63	(0.02)	0.59	(0.06)	0.00
GEDUCATION	3.56	(0.49)	3.57	(0.18)	3.55	(0.67)	0.82
GHOUSEHOLDSIZE	3.45	(0.25)	3.40	(0.14)	3.50	(0.31)	0.00
GFARMSIZE	2.14	(0.08)	2.10	(0.06)	2.18	(0.08)	0.00
GINCOME	2035.24	(879.85)	2109.30	(669.60)	1961.17	(1046.92)	0.22

Note: For all tests of means, the null hypothesis is that the means are equal against a two-sided alternative. The confidence level is at 5%.

Table 2.1 provides a brief picture of Sancha village. As one can note, the arable land resources are scarce in the village: the average area of paddy field (FARMSIZE) is only 2.13 mu (0.14 ha) per household. The labor force seems abundant (3.4 persons per household), but most are aged people (54 years old) and female farmers (61%). Their average education level is barely four years of primary school. This is a common situation in southwest China. Along with the development of the manufacturing sector, more and more rural households rely on off-farm activities for their livelihood. Since there is little off-farm employment in the countryside (for example, in Sancha village, the average annual off-farm income is only 1946 Yuan (311 US dollar)), rural households intend to migrate and work in the city to improve their livelihood. However, under the hukou system and rigid land tenure regime, rural households with rural hukou cannot sell their land and easily integrate into the city[12]. Consequently, the best strategy for rural households is for men to work in the city and for women work at home. It is estimated that more than 150 million Chinese farmers worked out of home in city (Cai and Wang, 2008). The feminization phenomenon is becoming prevalent in China (De Brauw et al., 2013).

[12]In China, the population is administrated by urban hukou and rural hukou according to an individual's permanent residence. In accordance, the social security and medical care schemes are distinct for the two types of hukou. People with rural hukou are thus not covered by the urban social safety nets, even if they work in the city. For compensation, they have the right of use of arable land for agricultural exploitation but without property rights, i.e. they cannot sell the land under their exploitation.

When we compare the organic farming adopters with non-adopters in Sancha village, some preliminary evidence should be noted. Firstly, there is significant difference between the two groups in terms of basketball match participation. 94% of organic adopters reported to have frequently participated in the basketball matches versus 17% of non-adopters. Secondly, the difference in peers' adoption rate is also significant. Whilst 83% of adopters' peers adopted organic farming, only 28% of non-adopters' peers adopted. Thirdly, most peer characteristics are also significantly different: for example, adopters have more aged and female peers with large household sizes and large farm size. To sort out all these correlations and to determine the importance of each, we need turn to a more rigorous econometric analysis.

2.5 Methodological framework

2.5.1 Literature review

In this section, we firstly undertake a brief literature review to guide our empirical analysis. The social network effect (also known as peer effect) is often studied in the diffusion of innovation in economics (Young, 2000; Rogers, 1995). Specifically in the domain of agricultural economics, the social network effect implies the diffusion of agricultural technologies in developing countries (Foster and Rosenzweig, 1996; Conley and Udry, 2001; Bandiera and Rasul, 2006; Munshi, 2004; Miguel and Kremer, 2003). In spite of its solid theoretic foundation, the empirical evidence of social network effect is ambiguous provided that the estimation is complicated.

In general, one needs to address three fundamental problems when estimating social network effect. The first is discussed by Manski (1993) and is commonly known as the "reflection problem". Basically, it refers to the difficulty of disentangling the endogenous social network effect from the exogenous contextual effect when using a "linear-in-means" model to estimate social network effect[13]. This could be regarded as a simultaneity problem in econometrics. The second is the endogenous formation of social networks. For instance, in our case, a farmer's participation in the basketball matches and his adoption of organic farming could be jointly determined by his intrinsic attributes (e.g. sociability and state of health) which are non-observable to the econometrician. The formation of the basketball network is thus endogenous. Thirdly, the effect of social network could be spuriously estimated if some correlated environmental effects were omitted by the econometrician. In our case, the socio-economic endowments may be family-specific (e.g. culture and expertise). These endowments are likely to be confounded with the social network effect.

To overcome these problems and achieve consistent estimation of social network effect, various methods have been proposed. For instance, one could rely on the nonlinearity between individual and group response, which is imposed by a discrete choice model as discussed by

[13]In the linear-in-means model, the outcome of each individual depends linearly on his own characteristics, on the mean outcome of his reference group and on its mean characteristics.

Brock and Durlauf (2000). One could also explore the exogenous variation in group size to achieve the identification (Lee, 2007; Boucher et al., 2012). Moreover, the overlapping structure of social networks could be explored to derive spatial instruments for the identification of social network effect (Bramoullé et al., 2009). Finally, as discussed by Moffitt and Valente (2001), the change of social network by policy intervention could be an exogenous source of identification. In our case, the policy intervention of the basketball matches was aimed at all farmers in the village, whereas some were hindered from attendance by their remote location from the court (given the evening scheduling of the matches) and family situation (children). Therefore, the special setting of the basketball matches provides a possibility of identification. We will turn back to the identification strategy in the section on econometric issues. Before that, we firstly turn to the definition of "social network" in our study.

2.5.2 Modeling of the social network in Sancha village

In the literature, egocentric data is usually collected to measure specific social networks, e.g. kinship networks and friendship networks (Wasserman and Faust, 1994). In this study, we aim to explore the social interactions in a broader scope of social activity. In the case of the basketball matches, it is difficult to distinguish between different kinds of interactions. For instance, a farmer may interact beyond his family and close friends. He may even get information from the conversations of others in the match. One may argue that it is unrealistic for a farmer to interact with all peers in the group. This is indeed true. However, a precise definition of social links also carries the potential risk of measurement errors and information omission. For a broad study of social network effect here, we decided to take into account all potential social links to define the social network of study.

Following previous discussions, the social network of Sancha village is composed of two parts: the family network and the basketball match extension. First of all, to represent the family network in mathematical terms, we construct a matrix $F = [f1_i f2_i f3_i f4_i]$ where row i represents the family belonging of the household i, columns $f1 - f4$ are four family dummies. This can be transformed into a symmetric matrix $W1$ that represents family-specific social links between household i and household j.

$$W1 = [w1_{ij}] = F \times F' \tag{2.1}$$

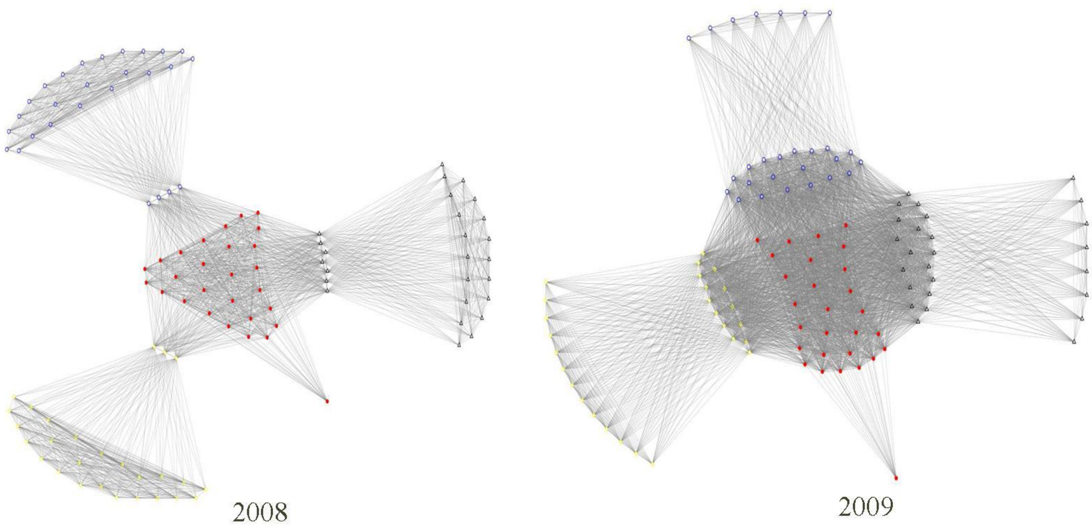
Next, participation in the basketball matches is assumed to extend family network $W1$. Similarly, the extension induced by participation in the basketball matches can be represented by a one column matrix $C = [c_i]$ where c_i is a dummy variable measuring household i's participation in the matches. It can also be transformed into a symmetric matrix $W2$:

$$W2 = [w2_{ij}] = C \times C' \tag{2.2}$$

By combining $W1$ and $W2$, we construct a symmetric matrix G to represent the extended social network, taking into account both family relationship and basketball match participation:

$$G \equiv W1 + W2 \tag{2.3}$$

By this definition, we implicitly assume that the social interactions within network $W1$ and $W2$ are of the same effect. Regardless of any particular network nature (e.g. family or basketball match), the social network effect that we identify is the mean effect within social network G. The matrix G is then normalized for subsequent use. With this modeling, we can visualize social network G in Figure 1.



Notes: Social networks are drawn according to author's survey and total community social network definition. The dark triangle, red point, yellow diamond and blue circle represent villagers in families 1, 2, 3 and 4 respectively. Villagers in the central zone are those who have reported to participate in the basketball match frequently.

Figure 1. The dynamic of social network in Sancha village

Figure 1 is produced with NodeXL using data collected by our survey. The nodes of different forms (dark triangle, red point, yellow diamond and blue circle) correspond to the households of the four families (Xu, Li, Huang and Lu), respectively. The edges represent the social links between households according to our definition of social network (either in the same family or participated in the basketball matches). To make it more intuitive, households who participated in the basketball matches are placed in the center of the graph. One can note that in 2008 (before the renovation of the court), a few households (mainly Li family) participated in the matches, and the social network was relatively sparse, whilst in 2009, more households were attracted to the matches and intensified the social network. This dynamic of the social network can be explored for the identification of the social network effect.

2.5.3 Econometric issues

Baseline study

As a benchmark of our empirical analysis, we firstly conducted a baseline study to test the relevance of the basketball matches on organic farming adoption with a simple model as follows:

$$Organic_{i,t} = \alpha_0 + \alpha_1 Basket_{i,t} + \alpha_2 X_{i,t} + F_s + T_t + \varepsilon_{i,t} \tag{2.4}$$

Here the dependent variable $Organic_{i,t}$ is household i's organic farming adoption, $BASKET_{i,t}$ is household i's participation in basketball matches at time t, $X_{i,t}$ control for a number of household socio-economic characteristics such as age, gender, education level, household size, farm size and off-farm income. These characteristics are expected to capture the human capital and physical capital of household. F_s are family dummies to control for unobservable family specific characteristics. T_t denotes a year dummy to capture common shocks related to the year.

With this specification, $Basket_{i,t}$ is susceptible to being endogenous due to unobservable characteristics of the farmer (for example, state of health and sociability). To address this problem, IV estimation is applied. Two instruments are available in our specific setting: the remoteness from the basketball court and the number of children in the household. In Sancha village, the national "one child" policy is loosened so that ethnic minority can have more than one child. The number of children is thus exogenous to determine household's incentive for basketball matches. On the other hand, the mountainous environment and the evening scheduling of the matches make a household's participation decision sensitive to a small geographical distance (5-15 minutes' walk). Yet such a small distance seems less likely to directly determine an important agricultural decision such as whether or not to adopt organic farming. To confirm this exclusion restriction, it could be checked by a Sargan over-identification test. This baseline regression is not only useful to confirm our research intuition, but also serves to check the validity of our instruments for subsequent use.

Identification of social network effect

Next, we set out to identify the social network effect in order to validate the mechanism underlying the baseline relationship. To this end, we estimate a model that describes the interdependent relationship between an individual's organic farming adoption decision and his peers' adoption decision within the predefined social network (Case, 1992; Manski, 1993; Brock and Durlauf, 2001; Moffitt and Valente, 2001):

$$Organic_{i,t} = \beta_0 + \beta_1 \frac{\sum_{j \in P_i} Organic_{j,t}}{n_i} + \beta_2 \frac{\sum_{j \in P_i} X_{j,t}}{n_i} + \beta_2 X_{i,t} + \tau_t + \varepsilon_{i,t}, \tag{2.5}$$

In the model, household i's organic farming adoption depends on the mean adoption rate of his peers in his network P_i. This social network effect is captured by coefficient β_1. In the notation of Manski (1993), it is called the *endogenous social effect*. Meanwhile, household i's decision also depends on the characteristics of his peers, which represent the *contextual effect* and captured by β_2. Also, a number of household socio-economic characteristics are controlled for by X. Finally, τ_t is a year dummy to capture the year shock and the error term $\varepsilon_{i,t}$ is the i.i.d disturbance with zero mean and an unknown variance associated with i.

We can write the structural model in a matrix notation:

$$Organic_{i,t} = \beta_0 + \beta_1 Organic_{i,t} + \beta_2 GX_{i,t} + \beta_3 X_{i,t} + \tau_t + \varepsilon_{i,t} \tag{2.6}$$

G is the social network matrix as predefined earlier. $G_{ij} = 1/n_i$ if i and j are in the same family or both participated in the basketball matches, and 0 otherwise. The objective of our identification is to disentangle the endogenous social network effect from the contextual effect and possible correlated environment effects. We will address these problems as discussed in the literature one by one.

First of all, to rule out the correlated effects specific to family, we compare household's organic farming adoption within the same family by adding family dummies ς_s $s \in 1...4$ in equation 2.6. Secondly, as discussed earlier, it is possible that a household may self-select into the basketball matches due to unobservable characteristics (for example, state of health or sociability). To address this concern, we will make use of the Heckman correction for the self-selection problem (Heckman, 1979). For a demonstration, we model the adoption and participation process with two separate equations:

$$Organic_{i,t} = \beta_0 + \beta_1 Organic_{i,t} + \beta_2 GX_{i,t} + \beta_3 X_{i,t} + \varsigma_s + \tau_t + \mu_{i,t} + \varepsilon_{i,t} \tag{2.7}$$

$$Prob(Basket_{i,t} = 1) = \delta_0 + \delta_1 GX_{i,t} + \delta_2 X_{i,t} + \delta_3 Z_{i,t} + \varsigma_s + \tau_t + \xi_{i,t} \tag{2.8}$$

The correlation $\mu_{i,t}$ and $\xi_{i,t}$ is the origin of self-selection problem. Using two exogenous variables $Z_{i,t}$ (i.e. remoteness and number of children) and making the strict assumption (that is $\mu_{i,t}$ and $\xi_{i,t}$ are mean zero, jointly and normally distributed with the variance-covariance matrix), the expectation of $\mu_{i,t}$ conditional on participation can be calculated using the formula below:

$$E[\mu_{i,t} | Basket_{i,t} = 1] = \iota \sigma_\mu \lambda_{i,t} \tag{2.9}$$

Of which, $\lambda_{i,t}$ is the Inverse Mills Ratio calculated from the residues predicted from participation equation 2.8.

$$\lambda(\xi_{i,t}) = \phi(\xi_{i,t}) / \Phi(\xi_{i,t}) \tag{2.10}$$

As such, to eliminate the self-selection problem, we can calculate $\lambda_{i,t}$ and explicitly control for it in the adoption equation as follows:

$$Organic_{i,t} = \beta_0 + \beta_1 GOrganic_{i,t} + \beta_2 GX_{i,t} + \beta_3 X_{i,t} + \beta_4 \lambda_{i,t} + \varsigma_s + \tau_t + \varepsilon_{i,t} \tag{2.11}$$

The third is the reflection problem. We need find appropriate instruments for $GOrganic_{i,t}$ (Bramoullé et al., 2009; Moffitt and Valente, 2001). Here, the key observation we make is that $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ are two candidates under two conditions: 1) $\lambda_{i,t}$ is significant 2) $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ are excludable from equation 2.11. The first condition relies on the assumption of the endogenous formation of the social network. The second condition of exclusion restriction is ensured by the assumption that a farmer's participation in the basketball matches should not be driven by his strategic behaviour based on his observation of peers' organic farming adoption. This crucial assumption is strong but seems to hold given the timing of our survey (i.e. one year beginning around the court renovation). During such a short period, any strategic behaviour based on complete observation of the entire social network is unlikely.

To ensure the exclusion restriction, we also need to control for both observable and non-observable characteristics (captured by $\lambda_{i,t}$) of the household in adoption equation 2.11. As suggested by other studies (Arcand and Fafchamps, 2011; Fafchamps and Lund, 2003; Conley and Topa, 2002), assortative matching is common in social network formation. Put another way, farmers' characteristics are similar within their network, which means $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ may correlate with $\lambda_{i,t}$ in the model. Finally, the exclusion restriction can be verified by the Sargan over-identification test.

In summary, under the reasonable assumption of exclusion restriction, our identification of the social network effect is achieved in three steps:

1. The participation equation 2.8 is estimated with two $Z_{i,t}$ (i.e. remoteness from the court and number of children) to calculate the Inverse Mills Ratio $\lambda_{i,t}$ (Maddala, 1983).

2. The assumption of endogenous formation of social network (i.e. $\lambda_{i,t} \neq 0$) is checked. If it holds, we construct two instruments $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ for subsequent use.

3. The adoption equation 2.11 is estimated by applying the IV estimation using $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ as instruments for $GOrganic_{i,t}$.

2.6 Results and discussion

2.6.1 Basketball matches and organic farming

As a starting point, we firstly regress our baseline model to test the relationship between farmers' participation in the basketball matches and their organic farming adoption. The result is reported in Table 2.2, which serves as a benchmark result and a check of our two instruments.

For the sake of comparison, we employ different estimators (probit and xtprobit), which yield consistent results. The results indicate that, with all else equal, a farmer's participation in the basketball matches will increase his probability to adopt organic farming by 28%. The effect of the basketball matches is positive and significant, which confirms the effectiveness and efficiency of basketball matches for farmers' organic farming adoption. To address the concern of the endogeneity problem of participation, we apply the IV estimation using household's remoteness from the court and the number of children as instruments. One can note that the statistics of the Sargan test don't reject the validity of our instruments, and the effect of the basketball matches remains significant with a magnitude of 0.26.

Regarding other determinants of organic farming adoption, the results highlight the role of women and education. It is plausible that female and more educated farmers care more about the health issues due to use of toxic chemical pesticides. This result is in line with other studies which also find education indispensable in the promotion of new technologies (Foster and Rosenzweig, 1996; Huffman, 2001). Hence, female and educated farmers' sensitivity and favor for organic farming should be noted and play an essential role in the promotion of organic farming. Farm size is also found to have a positive effect in favor of organic farming adoption. A conceivable explanation is that organic farming is associated with high risk (i.e. yield lost). A household with a large farm could alleviate the risk by allocating a small portion of its farm for experimentation. Finally, Li family (FAMILY2) is significantly related to organic farming. The result confirms the finding of our fieldwork that the household of Li family accumulated rich experience of organic farming during the early stages of experimentation. Their expertise sustained their choice of organic farming, as suggested by the result.

Table 2.2: Results of baseline regression

	Dependant Variable: ORGANIC(1/0)					
Estimator	PROBIT		XTPROBIT		IV-PROBIT	
BASKET	0.28***	(0.00)	0.28***	(0.00)	0.26***	(0.00)
AGE	1.98e-03	(0.13)	1.96e-03	(0.14)	2.15e-03	(0.15)
SEX	0.12***	(0.00)	0.12***	(0.00)	0.13***	(0.00)
EDUCATION	0.01**	(0.02)	0.01**	(0.02)	0.01**	(0.03)
HOUSEHOLDSIZE	0.01	(0.26)	0.01	(0.26)	0.01	(0.29)
FARMSIZE	0.09***	(0.00)	0.09***	(0.00)	0.09***	(0.00)
INCOME	1.42e-07	(0.95)	1.96e-07	(0.93)	1.76e-07	(0.95)
FAMILY2	0.30***	(0.00)	0.30***	(0.00)	0.34***	(0.00)
FAMILY3	-0.04	(0.43)	-0.04	(0.46)	-0.04	(0.44)
FAMILY4	0.07	(0.12)	0.07	(0.15)	0.07	(0.12)
YEAR	0.19***	(0.00)	0.19***	(0.00)	0.21***	(0.00)
Observations	216		216		216	
Log pseudolikelihood	-39.79				-124.46	
P-value Wald chi2	0.00		0.00		0.00	
Sargan test					0.98	

Notes: Average Marginal Effects are calculated for the coefficient and robust p-value reported in parentheses, with ***, ** and * denoting significance at the 1, 5 and 10 percent level respectively. P-value of Wald chi2 is presented. P-value of Sargan test is presented for the IV-probit estimator. First stage result is presented in Tables and figures.

2.6.2 Diffusion of organic farming through social network

The literature and our fieldwork provide a hypothesis to explain the relationship between the basketball matches and the adoption of organic farming, which is the social network effect. We thus attempt to identify the social network effect and we present the results in Table 2.3. We will follow the three-step identification with a discussion.

Table 2.3: Participation and social network effect

	Naive		Step1		Step2		Step3	
Dependant Var	ORGANIC		BASKET		ORGANIC		ORGANIC	
Estimator	OLS		PROBIT		OLS		IV	
GORGANIC	1.31***	(0.00)			0.35	(0.17)	0.67**	(0.01)
AGE	3.20e-03	(0.41)	0.01***	(0.00)	3.36e-03	(0.31)	3.66e-03	(0.34)
SEX	0.15	(0.11)	0.06	(0.29)	0.19***	(0.01)	0.15**	(0.01)
EDUCATION	0.02**	(0.03)	0.02***	(0.00)	0.03***	(0.00)	0.02***	(0.00)
FARMSIZE	0.09***	(0.00)	-0.04*	(0.08)	0.03	(0.26)	0.05*	(0.08)
INCOME	-3.65e-06	(0.49)	1.98e-06	(0.81)	-8.99e-06*	(0.07)	-8.53e-06	(0.17)
HOUSEHOLDSIZE	0.03	(0.15)	0.05**	(0.03)	0.08***	(0.00)	0.07***	(0.00)
GAGE	0.07	(0.54)	0.43***	(0.00)	0.10	(0.35)	0.11	(0.33)
GSEX	1.03	(0.68)	3.42*	(0.05)	4.59**	(0.02)	2.97	(0.14)
GEDUCATION	0.23**	(0.03)	0.82***	(0.00)	0.86***	(0.00)	0.71***	(0.00)
GFARMSIZE	0.17	(0.84)	-1.87***	(0.00)	-1.79**	(0.04)	-0.99	(0.28)
GINCOME	-2.28e-04	(0.32)	1.20e-05	(0.97)	-5.4e-04***	(0.00)	-5.17e-04**	(0.02)
GHOUSEHOLDSIZE	0.93	(0.18)	1.61**	(0.04)	2.76***	(0.00)	2.43***	(0.00)
REMOTENESS			-0.14***	(0.00)				
KID			0.05*	(0.09)				
IMR					0.28***	(0.00)	0.26***	(0.00)
Observations	216		216		216		216	
R2/Log likelihood	0.64		-51.07		0.73		0.73	
F-test	0.00				0.00		0.00	
Sargan test							0.71	

Notes: Average Marginal Effects are calculated for probit estimation in col2; Robust p-value is represented in parentheses, with ***, ** and * denoting significance at the 1, 5 and 10 percent level respectively. R2 value is reported for OLS and IV estimation, log pseudo likelihood value is reported for probit estimation. The p-value of Sargan test is reported for IV estimation. The family and year dummies are controlled except for naive estimation in col1.

Social activity and its constraints

In the first column of Table 2.3, we present the result of a "naive" estimation of social network effect. One can note that the coefficient of the social network effect is significant and quite large (i.e. 1.31), which appears too good to be true. On the other hand, most contextual effects are non-significant. This raises doubts about the spurious identification of social network effect as discussed by Manski (1993). We will later compare this result with our three-step identification result and find that the “naive” result is not robust.

In a first step, column two reports the estimation result of the participation equation 2.8 by probit estimator. The result is instructive in understanding the advantages and constraints of social activity in rural areas and in guiding other NRR project. Firstly, we find that education and household size are positively correlated with household participation in the basketball matches. In addition, seniors are also more interested by the basketball match. It is not surprising since seniors generally have more spare time and less life pressure. This result is in line with Putnam (2001)’s finding of cohort effect where seniors belong to more organisations than younger people. In rural China, the role of seniors is recognized in other NRR projects. For instance, Wang et al. (2009) report cases of successful NRR co-operatives which are founded on the basis of senior association.

On the other hand, farm size is found to impede a household’s participation in the basketball matches. In our analysis, the farm size may capture the activity of agricultural production. A large farm probably implies more agricultural work and less spare time. This result suggests a potential constraint of social activity in big villages, which is supported by Wang et al. (2009)’s finding stating that the NRR has encountered more difficulties in large villages. The feasibility of social activity thus remains questionable in larger villages where the agricultural burden is usually heavy. Moreover, we find the remoteness from the court significantly hindered a household’s participation in the basketball matches. This also questions the efficiency of social activities in big villages where households are sparsely located.

For peers’ influence, the signs and significance are similar with an individual’s own characteristics. For instance, a household with more senior, educated, female and large household peers in its social network is more likely to participate in the matches, whilst more peers with large farm has the opposite effect. The result suggests an assortative matching in the formation of social network in our case (Arcand and Fafchamps, 2011; Fafchamps and Lund, 2003; Conley and Topa, 2002). Consequently, the problem of the endogenous formation of social network should be taken into account in our following analysis.

Effect of social network on organic farming development

We continue with the identification of the social network effect. In column three, the Heckman Inverse Mills Ratio (λ) is calculated and controlled in the model. One can note that the coefficient of IMR is significant, which suggests the presence of a self-selection problem. A likelihood ratio test is thus performed. The rejection of a null hypothesis confirms this assumption and supports the necessity of Heckman correction. Moreover, the significant IMR enables us to construct instruments $G\lambda_{i,t}$ and $G^2\lambda_{i,t}$ for subsequent identification use.

In column 4, we address the reflection problem by applying the IV estimation. The model we estimate is a Linear Probit Model (LPM), which is simple and intuitive for estimation and interpretation. Another advantage of the LPM model is the comprehensive statistical tests that enable us to check assumptions, such as exclusion restriction of our instruments. Finally, given the survey nature of our data, it is possible that the errors of respondents are correlated. To eliminate this concern, a bootstrap approach is applied to the estimation. For the result, we firstly note that the magnitude of the social network effect is reduced by 50% compared to the naive estimation. However, it remains positive and statistically significant at the 5% level. The result indicates that, all else equal, 10% growth in the fraction of peers who adopt organic farming will increase 6.7% of the probability that a household also adopts organic farming. This is a quite large social multiplier effect in comparison with other studies in the literature (Conley and Udry, 2001; Bandiera and Rasul, 2006). With this result, we can justify that the collective action for sustainable agricultural development is possible within the social network extended by the basketball matches. This understanding is crucial for government or development agencies with the aim of promoting sustainable agriculture in poor rural areas. Apart from conventional promotion, such as advertising campaigns and subsidies, agencies could also rely on the social network effect for technology diffusion. Social or cultural activities are cost-effective means for networking, as suggested by our results.

For the contextual effects, we find more significant coefficients than in the case of naive estimation. These contextual effects are also important for our understanding about the environmental effect and guide other NRR projects. For instance, more educated and larger household peers encourage the adoption of organic farming, whilst richer peers discourage the adoption. Given the knowledge and labor intensity of organic farming, one plausible explanation is that farmers may share knowledge as well as labor within their social network. By contrast, peers' off-farm income may capture off-farm employment opportunities provided by peers. These opportunities will certainly pose labor competition for organic farming and can discourage its adoption. With these understandings in mind, NRR project should identify poor but labor abundant villages for sustainable agricultural development and could provide education or extension service at village level.

Finally, the effects of household's characteristics are meaningful and useful in understanding household's constraints for organic farming development. We note here three key characteristics of household that favor organic farming: female head, education and labor. As explained earlier, Chinese rural society is characterized by a massive exodus of male labor. This phenomenon represents both constraints and opportunities for organic farming development. On one hand, we should recognize the critical role of women in rural society and rely on them for a shift to sustainable agriculture. On the other hand, more extension services (i.e. environmental education and technical training) are needed to reinforce farmers' capacity for sustainable development.

2.6.3 Robustness check

For the robustness check, we firstly explore the panel structure of our dataset to estimate a within model which relies on the variation of social network due to policy intervention of the basketball matches. The advantage of a within model is to eliminate any time-invariant correlated effects. Also, we can combine the advantages of the within model and the IV approach to run a Within-2SLS estimation. These exercises are useful to compare with previous results using the Heckman-IV method.

Secondly, as discussed by Bramoullé et al. (2009), we can construct spatial instruments G^2X which consist of characteristics of a peer's peers to identify the social network effect. In our case, the overlapping network structure makes it possible to apply the estimator of Bramoullé et al. (2009) (henceforth BDF). For concerns of endogenous formation of social network (that is farmers' self-selection into the basketball matches) and correlated effects, we will control for IMR in the model and estimate a within model.

Finally, the social network effect may be heterogeneous. The intuition is that if the social network effect is due to information spillover, organic experts who have precise information about organic farming should be less susceptible to the social network effect. It could be negative if the social network becomes so large that the cost of network maintenance is high (see more explanation of Bandiera and Rasul (2006)). To check for the heterogeneous social network effect, we conduct a difference-in-difference type analysis based on the timing of organic adoption. In practice, we construct a dummy variable C which indicates "0" for organic experts (i.e. households who participated in the PCD experiment) and "1" for new adopters (i.e. households who adopted organic farming in 2009). The dummy is then crossed with the variable $GORGANIC$ to construct a new variable $C*GORGANIC$ and included in the model. Finally the estimation is made by within and within-2SLS estimators for comparison. Intuitively, we expect that the sign of $GORGANIC$ to be non-significant or negative, whereas the cross term $C*GORGANIC$ should be positive and significant.

Let's first consider the results of the within and BDF estimations in Table 2.4. In all of these estimations, the social network effect is significant and positive. The magnitude of the coefficient ranges from 0.60 to 0.79. Our conclusion of a large social multiplier effect is thus not rejected by the robustness check. Moreover, the role of women, education and labor force favor organic adoption, whilst off-farm activity is the major competitor for organic farming. All these results are consistent with our previous findings.

Table 2.4: Robustness check (I)

	Dependant variable: ORGANIC(1/0)							
Estimator	WITHIN		WITHIN-2SLS		BDF		BDF-WITHIN	
GORGANIC	0.60**	(0.04)	0.76***	(0.01)	0.60***	(0.01)	0.79***	(0.00)
AGE	0.65**	(0.01)	0.56**	(0.01)	3.60e-03	(0.26)	0.54**	(0.02)
SEX					0.16**	(0.01)		
EDUCATION					0.02***	(0.00)		
FARMSIZE	-0.03	(0.53)	-0.02	(0.73)	0.05*	(0.06)	-0.01	(0.76)
INCOME	6.67e-06	(0.44)	6.78e-06	(0.42)	-8.62e-06*	(0.07)	6.81e-06	(0.42)
HOUSEHOLDSIZE	0.09	(0.17)	0.10	(0.13)	0.07***	(0.00)	0.10	(0.13)
GAGE	-0.09	(0.51)	-0.07	(0.56)	0.11	(0.28)	-0.07	(0.58)
GSEX	6.58***	(0.00)	5.96***	(0.00)	3.31*	(0.06)	5.83***	(0.01)
GEDUCATION	0.61***	(0.00)	0.56***	(0.00)	0.74***	(0.00)	0.55***	(0.00)
GFARMSIZE	-0.87	(0.32)	-0.44	(0.63)	-1.16	(0.15)	-0.36	(0.67)
GINCOME	-5.4e-04***	(0.00)	-5.3e-04***	(0.00)	-5.2e-04***	(0.00)	-5.3e-04***	(0.00)
GHOUSEHOLDSIZE	2.31***	(0.00)	2.19***	(0.00)	2.50***	(0.00)	2.17***	(0.00)
IMR	0.24***	(0.01)	0.22**	(0.01)	0.27***	(0.00)	0.22**	(0.02)
Observations	216		216		216		216	
R-squared	0.74		0.74		0.73		0.74	
F-test	0.00		0.00		0.00		0.00	
Sargan test			0.13		0.45		0.15	

Notes: Robust p-value in parentheses with ***, ** and * denoting significance at the 1, 5 and 10 percent level respectively. The P-value of Sargan test is presented for IV estimations in col 2, 3 and 4; The family and year dummies are controlled in all estimations; BDF refers to the estimator of spatial instrumentation as discussed by Bramoullé et al. (2009).

Next, let's look at the heterogeneous effect of the social network with the difference-in-difference analysis in Table 2.5. As expected, $GORGANIC$ becomes negative, whereas the cross term $C * GORGANIC$ is significantly positive. This result indicates that the adoption probability of organic experts is indeed decreasing along with the increasing number of participants in the social network. This could be due to their strategic behaviour given their complete information about the niche market for organic produce. By contrast, the social network effect is much stronger for new adopters, who have no comprehensive information about organic farming. Taken together, this result suggests that information spillover is a conceivable explanation for the social network effect identified in our study. However, the result doesn't eliminate other mechanisms, such as altruism and social pressure, which may also explain the social network effect. More specific data setting is needed to disentangle these mechanisms and we will leave this for a future study.

Table 2.5: Robustness check (II)

Dependant variable: ORGANIC(1/0)				
Estimator	WITHIN		WITHIN-2SLS	
GORGANIC	-1.55***	(0.00)	-2.44***	(0.00)
C*GORGANIC	1.57***	(0.00)	2.43***	(0.00)
AGE	0.96***	(0.00)	0.99***	(0.00)
FARMSIZE	0.01	(0.12)	-1.25e-03	(0.90)
INCOME	1.26e-07	(0.42)	3.63e-07	(0.20)
HOUSEHOLDSIZE	-0.01*	(0.07)	-0.02	(0.20)
GAGE	-0.16***	(0.00)	-0.10**	(0.02)
GSEX	-0.23	(0.80)	1.11	(0.52)
GEDUCATION	0.13	(0.32)	0.58**	(0.02)
GFARMSIZE	1.14***	(0.00)	0.64	(1.18)
GINCOME	-4.33e-04***	(0.00)	-2.60e-04*	(0.08)
GHOUSEHOLDSIZE	-1.31***	(0.00)	-2.06***	(0.00)
C*GAGE	0.17***	(0.00)	0.10**	(0.02)
C*GSEX	0.04	(0.96)	-1.11	(0.51)
C*GEDUCATION	-0.15	(0.23)	-0.58**	(0.02)
C*GFARMSIZE	-1.10***	(0.00)	-0.70	(0.13)
C*GINCOME	4.59e-04***	(0.00)	2.78e-04*	(0.05)
C*GHOUSEHOLDSIZE	1.21***	(0.00)	2.03***	(0.00)
IMR	4.06e-04	(0.87)	2.18e-03	(0.41)
Observations	154		154	
R-squared	0.99		0.99	
F-test	0.00		0.00	
Sargan test			0.93	

Notes: Robust p-value in parentheses; With ***, ** and * denoting significance at the 1, 5 and 10 percent level respectively. The family and year dummies are controlled for in both estimations. The P-value of Sargan test is presented for IV estimation.

2.7 Conclusion

This chapter sketches an alternative scenario for the development of sustainable agriculture such as organic farming in the context of New Rural Reconstruction. We examine an original example in Sancha village where the organisation of basketball matches is employed to promote organic farming development. Our fieldwork and household level analysis reveal a large social multiplier effect within the extended social network in the village, which provides empirical evidence for the impact of social reconstruction on the diffusion of organic farming in rural China.

In developing countries, the achievement of sustainable agricultural development seems to strongly depend on colossal government investment in formal institutions which is often constrained by the scarcity and inefficiency. Alternatively, the New Rural Reconstruction proposes a cost-effective solution which relies on informal institutions, such as social networks. Regarded as a form of social capital, social networks are indeed widespread in rural areas. Smallholder farmers form social networks on the basis of kinship and friendship, as well as for social and cultural activities. These social networks are essential for farmers' social learning, risk sharing, labor and finance cooperation and thus constitute the solid social foundation for farmers' collective action to achieve sustainable agricultural development.

Tables and figures

Definition and description of variables

ORGANIC	Farmer's self report of organic farming adoption. It's a binary variable code "1" if at least one plot of paddy field is under organic management. Code "0" otherwise.
BASKET	Farmer's report of basketball game participation. It's a binary variable code "1" if household participates in the basketball game more than 3 times per month during the year. Code "0" otherwise.
AGE	Age of household head.
SEX	Gender of household head. Code "1" for woman, "0" for man.
EDUCATION	Education level of household head. Code "0" for illiteracy, "1" for primary school first grade, "2" for primary school second grade, "3" for primary school third grade, "4" for primary school fourth grade, "5" for primary school fifth grade, "6" for primary school sixth grade, "7" for middle school first grade, "8" for middle school second grade, "9" for middle school third grade, "10" for high school first grade, "11" for high school second grade, "12" for high school third grade.
HOUSEHOLDSIZE	Number of permanent residents of the household.
FARMSIZE	Area of cultivated paddy field during the reference year, the unit is "Mu"(0.067 ha).
INCOME	Off-farm income of off-farm activities, the unit is "Yuan".
REMOTENESS	The distance to the basketball court measured by walk time. Code "1" for less than 5 minutes, "2" for 5 to 15 minutes, "3" for more than 15 minutes.
KID	The number of kids under 5 years old and taken care by the household head.

First stage regressions

	Baseline study		Heckman-IV		Heckman-IV(WITHIN)		BDF		BDF(WITHIN)		DIF-DIF		DIF-DIF	
Dependant variable	COMMUNITY		GORGANIC		GORGANIC		GORGANIC		GORGANIC		C*GORGANIC		GORGANIC	
REMOTENESS	-0.29***	(0.00)												
KID	0.06	(0.10)												
GIMR			-0.21	(0.39)	-0.32	(0.12)								
G2IMR			1.65***	(0.00)	1.78***	(0.00)								
G2AGE							-1.17***	(0.00)	-1.17***	(0.00)				
G2SEX							19.41***	(0.00)	19.59***	(0.00)				
G2EDUCATION							-0.14***	(0.01)	-0.12*	(0.07)				
G2FARMSIZE							-0.75***	(0.00)	-0.76***	(0.00)				
G2INCOME							-3.86e-04***	(0.00)	-4.40e-04***	(0.00)				
G2HOUSEHOLDSIZE							-0.38**	(0.01)	-0.26	(0.16)				
AGE	1.26e-03	(0.50)	1.81e-03***	(0.00)	0.34***	(0.00)	-2.43e-04	(0.14)			2.46e-03	(0.73)	0.40***	(0.00)
SEX	3.63e-03	(0.95)	0.09***	(0.00)			0.01**	(0.03)						
EDUCATION	1.37e-03	(0.88)	0.01***	(0.00)			3.82e-04	(0.59)						
FARMSIZE	0.01	(0.78)	-0.07***	(0.00)	-0.07***	(0.00)	-2.07e-03	(0.24)	-4.85e-03	(0.25)	1.12e-03	(0.26)	-4.87e-04	(0.93)
INCOME	-1.09e-06	(0.77)	-1.45e-06	(0.39)	-4.87e-06**	(0.01)	-5.06e-08	(0.86)	6.77e-07	(0.13)	1.45e-07	(0.57)	3.16e-07	(0.33)
HOUSEHOLDSIZE	0.01	(0.52)	0.03***	(0.00)	0.02	(0.20)	-0.01***	(0.00)	-2.02e-03	(0.64)	6.06e-04	(0.66)	-5.42e-03	(0.38)
GAGE			0.06***	(0.00)	0.06	(0.10)	-0.05***	(0.00)	-0.05***	(0.00)	-6.94e-03**	(0.02)	-0.04	(0.14)
GSEX			3.72***	(0.00)	3.04***	(0.00)	1.19***	(0.00)	1.04***	(0.00)	-0.04	(0.48)	0.45	(0.49)
GEDUCATION			0.40***	(0.00)	0.29***	(0.00)	0.03	(0.24)	0.01	(0.65)	-0.01	(0.26)	0.24***	(0.00)
GFARMSIZE			-2.56***	(0.00)	-2.51***	(0.00)	-0.08	(0.16)	-0.06	(0.53)	0.04	(0.20)	0.25	(0.39)
GINCOME			-3.84e-05	(0.34)	-1.32e-05	(0.71)	-2.28e-05	(0.13)	-1.76e-05	(0.35)	-7.73e-07	(0.91)	-9.95e-05	(0.31)
GHOUSEHOLDSIZE			1.07***	(0.00)	0.88***	(0.00)	-0.23***	(0.00)	-0.27***	(0.00)	-0.01	(0.46)	-0.84***	(0.00)
IMR			0.03	(0.29)	0.04	(0.19)	0.03***	(0.00)	0.03***	(0.00)	-0.01***	(0.00)	-3.30e-03	(0.40)
C*GAGE											0.02***	(0.00)	0.04	(0.10)
C*GSEX											2.32***	(0.00)	1.65**	(0.01)
C*GEDUCATION											0.12***	(0.00)	-0.15**	(0.01)
C*GFARMSIZE											0.21***	(0.00)	-0.08	(0.77)
C*GINCOME											-6.10e-05***	(0.00)	4.97e-05	(0.62)
C*GHOUSEHOLDSIZE											0.43***	(0.00)	1.16***	(0.00)
C*G2AGE											0.53***	(0.00)	0.24***	(0.01)
C*G2SEX											44.99***	(0.00)	41.26***	(0.00)
C*G2EDUCATION											2.55***	(0.00)	2.14***	(0.00)
C*G2FARMSIZE											5.14***	(0.00)	4.25***	(0.00)
C*G2INCOME											-1.16e-03***	(0.00)	-1.11e-03***	(0.00)
C*G2HOUSEHOLDSIZE											9.98***	(0.00)	8.42***	(0.00)
Observations	216		216		216		216		216		154		154	
R2/Log pseudolikelihood	-80.03		0.88		0.88		0.89		0.89		0.89		0.89	

Notes: Average Marginal Effects are calculated for probit estimation in col1; Robust p-value in parentheses; With ***, ** and * denoting significance at the 1, 5 and 10 percent level respectively; BDF refers to the estimator of spatial instrumentation as discussed by Bramoullé et al(2009); The family and year dummies are controlled for in all equations.

Chapter 3

Case II: The Environmental Efficiency of Non-Certified Organic Farming*

3.1 Introduction

Achieving the balance between agricultural yield and the preservation of the agro-environment has always been the biggest challenge in agricultural development. Within this context, the debates about the sustainability of conventional and organic farming have never ceased (Avery, 1998; Pretty and Ball, 2001; Badgley et al., 2007; Connor, 2008). This debate is now becoming a critical and urgent issue in the 21st century, as the ever-increasing world population requires higher agricultural yields whilst the deterioration of the agro-environment is becoming more and more serious due to modern agriculture's excessive dependence on environmentally detrimental inputs.

Advocates of organic farming argue that organic farming is more environmentally friendly given its exclusion of synthetic inputs, i.e. pesticides, herbicides and fertilisers. Studies show that organic farming has significant environmental benefits in terms of agricultural pollution reduction, soil and water conservation, soil fertility recovery, ecological health and biodiversity improvement. This argument has been supported by world institutions who have promoted organic farming on a global scale (Willer et al., 2009; FAO, 2002; IFAD, 2002; WorldBank, 2009; Twarog, 2006; Kilcher, 2007; Hine et al., 2008). On the other side of the debate, critics of organic farming stress the lower productivity of organic farming. Evidences show that conversion to organic farming could reduce agricultural productivity by 20-50% in Europe and North America (Avery, 1998; Connor, 2008; Mayen et al., 2010).

Moreover, an often neglected concern involves the pollution of organic nutrients. Indeed, excessive use of external nutrients from organic sources also has a negative environmental impact. For example, the leaching of organic nitrates can cause water pollution, and ammonia volatilization of animal manure is a main source of greenhouse gas from agriculture (Pretty, 1995; Kirchmann et al., 1998). Therefore, to evaluate agricultural sustainability, one must take account of both agricultural productivity and efficient use of external nutrients. While many studies have focused on the productivity of organic farming (Avery, 1998; Connor, 2008; Pretty and Ball, 2001; Badgley et al., 2007), little attention has been given to the study of nutrient use in organic farming, especially for non-certified organic farming in developing countries[1].

*This chapter is an adapted version of an article submitted to *Environmental and Resource Economics*.

[1] Organic farming systems and products are not always certified and are referred to as "non-certified organic farming or products". Non-certified organic farming systems are prevalent in developing countries although it

In the literature of efficiency study, Reinhard et al. (1999) propose an indicator of environmental efficiency (EE for short) which is defined as the ratio of minimum feasibility to the observed use of an environmentally detrimental input at given output level. In other words, the indicator of EE measures the efficient use of environmentally detrimental inputs in agriculture production. This measure is appropriate for the evaluation of organic farming systems and provides useful insights into its environmental performance compared to conventional farming systems. In this chapter, we contribute to the literature by applying the environmental efficiency to evaluate smallholder paddy rice production in Sancha village, where non-certified organic farming was introduced in the context of the New Rural Reconstruction movement (see chapter 1 and chapter 2). Specifically, we focus on the efficient use of pure nitrogen, the most important nutrient input for paddy rice production. Meanwhile, it is also the biggest pollutant to air and groundwater resulting from agricultural production in China (Zhu and Chen, 2002; Ju et al., 2007)[2].

Using plot-season level survey data and agronomic experiment data, we gathered ourselves in the village, we firstly test the hypothesis of a "technology gap" between non-certified organic and conventional farming to determine the right specification of the production function. We then calculate environmental efficiency scores using a Stochastic Frontier Analysis (SFA) approach for both organic and conventional plots. Finally, we compare the calculated environmental efficiency scores between organic and conventional farming using estimation methods. The panel structure of data (5 seasons from 2008 to 2010) also allows us to investigate the evolution of EE over time.

Our case study demonstrates that for smallholder rice production, conversion to organic farming does not reduce the actual rice yield if chemical fertilizers are successfully substituted with organic nutrients. There is no significant "technology gap" between organic and conventional farming in smallholder environment. However, organic farming is not necessarily more environmentally efficient than conventional farming at high nutrient levels, which is mainly due to the inexperience of newly converted farmers in organic farming, especially during the initial conversion period from conventional to organic farming. Therefore, to maintain the environmental efficiency of organic farming, more external support such as technical training and environmental education are needed to accompany farmers during the conversion period.

The remainder of this chapter is organized as follows. Section 2 presents the organic farming project in the village. Section 3 describes the methodological framework and empirical method. Section 4 gives details of the data. Section 5 discusses the main results and Section 6 concludes.

3.2 Organic and conventional paddy rice production

Originally dedicated to produce high quality products for exportation, organic farming has now become a rural development strategy in China. Since 2003, vibrant organic communities have been observed in rural China in conjunction with the social movement of the New Rural Reconstruction that was initiated by scholars, students and social activists. Diverse models such as farmer's co-ops, farmer-participatory development and Community Supported Agriculture

is difficult to quantify to what extent.

[2]Environmental efficiency can be derived from different models such as the one of Cuesta et al. (2009) in which environmental damage is analysed through "bad output" modelling. In our case study, this strategy cannot be implemented because we have no information regarding the environmental damage caused by rice farming. For instance, we have no information on water or air pollution. For this reason, we focus only on the efficient use of an environmentally detrimental input, i.e., pure nitrogen.

(CSA) have recently emerged to promote organic farming in China (Day, 2008; Pan and Du, 2011a). In this study, we will focus on one of these alternative models in southern China.

The study area is located in Sancha village, a small village in Hengzhou county of Guangxi province (See Chapter 1 for the location of Sancha village). Given its remote situation and poverty, Sancha village maintains its old tradition of paddy rice production, e.g., two crop seasons of rain fed culture, cattle tillage and the use of cow dung fertilizer. The average chemical fertilizer application level is about 16.76 kg per mu (1 mu = 1/15 ha) in the village, which is much lower than the average provincial level of 26.24 kg per mu[3]. Therefore, both the traditional agricultural practice and the well preserved natural environment favor the development of organic farming in this village.

In 2005, an organic farming project was introduced to the village by the local Maize Research Institution (GMRI) in partnership with an NGO called Partnerships for Community Development (PCD), with the aim of promoting organic paddy rice production. This project began with participatory experimentation among a small group of farmers. During the experimentation period, the PCD provided strong technical and marketing support (CSA) to encourage conversion. By means of these participatory farmer experimentations, organic farmers found a suitable nutrient formula to substitute the chemical fertilizer by self–produced compost and traditional organic inputs[4]. With respect to pest control, farmers have adopted the integrated rice–duck culture system and the use of traditional medicinal plants, which appear to be efficient in preventing certain pests[5]. Table 3.1 gives more details about the difference between organic farming and conventional farming in Sancha village.

Table 3.1: Organic farming *versus* conventional farming in Sancha village

	Organic	Conventional
Seeds	Hybrid rice CY998, Traditional rice varieties: BX139, GF6, GF2, BGX, SYZ	Hybrid rice CY998
Fertilizers	Compost(30% fish powder, 30% bone powder, 30% peanut bran, 10% straw ash), Cow dung, Hen manure, Pig manure, Bio gas slurry, Green manure	Cow dung, Pig manure, Green manure, Compound fertilizer, Urea
Pest control	Duck, Chinese medical plant	Triazophos, Avermectins
Weed control	Duck, Hand weeding	Pretilachlor

Source: local agronomist of PCD

As one can note from table 3.1, the organic farming is more environmentally friendly comparing to conventional farming. The use of chemical fertilizers and pesticides are strictly prohibited. Farmers adopt their own formula of fertilizers (i.e., compost, cow dung, pig manure, hen manure etc.) and seeds according to the availability and specific soil condition. More ecological methods such as duck raising have been integrated into the paddy rice production, which is

[3]Data comes from our household survey at the village-level and from the 2011 Guangxi Statistical Year Book at the provincial level.

[4]Compost is produced by farmers using fish powder, bone powder, tea bran, peanut bran and bio gas slurry.

[5]The integrated rice–duck system consists of organic rice culture and, in the mean time, raising ducks in the paddy to prevent the growth of weeds and pests.

expected to achieve the recurrence of agro-ecosystem. Although without official organic certification, Sancha's organic farming corresponds to the definition of non-certified organic farming according to FAO (Scialabba and Hattaam, 2002).

After three years of experimentation, the project entered into a novel phase of scaling up. The year of 2009 was a critical time point of the project. Thanks to the improved social networks, more farmers got access to information about the organic farming project[6]. An acceleration of conversion to organic farming was observed in 2009. At the end of 2009, 73 percent of farmers in the village had conducted experiments on their paddy land. However, due to the limited resource of PCD, the technical support and environmental education was not able to cope with such a rapid expansion of organic farming. We note that although organic farming was universally accepted primarily due to its high price premium, newly converted farmers were still concerned about the loss of yield due to conversion.

To investigate the performances of organic and conventional farming in Sancha village, we collected data on inputs and output of paddy rice production by means of a household survey. Combined with the agronomic experimentation data of nitrogen content for each input provided by the local agronomist (see Table 3.10 in the Tables and figures for more details), we were able to calculate the pure nitrogen input as well as the soil surface nitrogen balance for both systems[7]. Table 3.2 presents a comparative summary of agricultural and environmental performance between conventional and organic farming during five consecutive crop seasons (from 2008 to 2010).

Table 3.2: Performance of organic and conventional farming in Sancha village

	Yield (kg/mu)			Nitrogen (kg/mu)			Nitrogen balance (kg/mu)		
	Organic	Conv	dif	Organic	Conv	dif	Organic	Conv	dif
Season 1	360.6(84.1)	363.3(94.1)	ns	13.3(3.2)	15.0(4.0)	**	0.0(3.7)	1.7(3.4)	**
Season 2	313.7(92.6)	323.7(92.8)	ns	12.1(3.3)	12.9(3.8)	ns	-0.1(3.7)	0.5(3.3)	ns
Season 3	339.0(91.8)	363.0(97.5)	*	15.4(4.5)	14.9(3.8)	ns	2.6(4.8)	1.6(3.2)	*
Season 4	301.9(86.8)	316.5(102.8)	ns	14.4(3.9)	12.5(3.7)	***	2.5(4.1)	0.2(3.1)	***
Season 5	363.5(72.8)	362.5(90.3)	ns	15.2(3.8)	14.6(3.6)	ns	1.8(4.1)	1.3(3.1)	ns

Notes: Data from the author's household survey and agronomic experimentation data provided by the local agronomist. 1 mu = 1/15 ha. The mean value is presented with standard deviation in parentheses. Seasons 1–2, 3–4 and 5 cover 2008, 2009 and 2010 separately. *** statistical significance at 0.1%, ** statistical significance at 1%, * statistical significance at 5%. "ns" means non–significant.

From Table 3.2, we note that organic farming has successfully coped with conventional farming in terms of yield. There has been no significant difference between organic farming and conventional farming in five crop seasons. This is in line with observations from other developing countries (Zhu et al., 2000; Pretty et al., 2003) and can probably be explained by the similar pure nitrogen input in the village. As one can note, during the scale-up period (since season three in 2009), organic farmers tended to use more pure nitrogen than their conventional counterparts. This is indeed not surprising and has already been highlighted in the literature. For instance, Hessel Tjell et al. (1999) and Torstensson (2003) have reported that mean use of nitrogen in organic systems is close to that of conventional systems in Sweden. This phenomenon could be explained by the smallholder production on tiny plots, where it

[6]More details about the social network construction in the village can be found in (Renard and Guo, 2013).

[7]The nitrogen balance is calculated at the soil surface level, following the method of OECD (2001), as the difference between the total quantity of pure nitrogen entering and the quantity of pure nitrogen leaving the soil surface over one production cycle. Since the aim of this approach is to investigate the global environmental impact of rice production, we do not distinguish between the loss of nitrogen to ground water and air separately.

is quite possible to substitute chemical nitrogen with organic nitrogen. However, it is also certainly due to the behavior of newly converted farmers to organic farming in Sancha village. According to the head of the village: "Since they (newly converted farmers) have less experience and confidence, they would generally apply more compost or animal manure for fear of yield loss from conversion."

Regarding the environmental impact, we take a look at the nutrient budgets by the indicator of Soil Surface Nitrogen Balance. A persistent deficit in nutrient budgets might indicate mining of soil nutrients, whilst a persistent surplus might indicate potential environmental pollution (OECD, 2001). We note that, at the mean level, both organic and conventional farming have displayed a varying nitrogen surplus, ranging from -0.1 kg per mu to 2.6 kg per mu. Compared to other Chinese provinces, the nitrogen surplus level in Sancha village is still low (Sun and Bouwman, 2008; Wang et al., 2007) while compared to its neighbor countries such as Thailand, Bangladesh and Vietnam, it appears to be at a similar or higher level (Wijnhoud et al., 2003; Hossain et al., 2012; Mussgnug et al., 2006). Once again, the nitrogen balance indicates a significant loss of environmental performance for organic farming during the scale–up period, which highlights the necessity of nitrogen optimization.

From this preliminary comparative examination, we find that organic farmers in Sancha village have achieved a satisfactory yield by substituting the chemical fertilizers with self–produced organic fertilizers. This is a big success from an economic point of view. However, the environmental cost is still high as indicated by high pure nitrogen input and nitrogen accumulation in the soil, especially during the scale-up period. Therefore, in order to determine the sustainability of organic farming, we will need another indicator with respect to nitrogen-use efficiency which takes into account both yield and environmental cost. For this purpose, we now turn to the indicator of environmental efficiency (EE) using the stochastic frontier analysis (SFA).

3.3 Methodological framework

The term of environmental efficiency used in this study is defined by the minimum use of pure nitrogen for a given level of yield. This environmental efficiency is different from conventional technical efficiency (TE) and stresses the efficient use of pure nitrogen, and thus the efficiency of environment preservation. Environmental efficiency is calculated from technical efficiency with the classic approach of SFA. We apply a two–step approach here as proposed by Reinhard et al. (1999). Environmental efficiency is firstly calculated from technical efficiency using a stochastic frontier analysis and then used as a dependent variable to investigate the environmental efficiency of organic farming.

3.3.1 Calculating environmental efficiency with a SFA model

To determine the environmental efficiency of organic farming, we need first to calculate this efficiency. One way to achieve this is to introduce environmental variables into a traditional production function in order to derive environmental efficiency from adjustments of conventional measures of technical efficiency.

Technical efficiency is first derived from a production frontier under the hypothesis that a non–optimal use of production factors by farmers, i.e., an X–inefficiency (Leibenstein, 1966), is the effect of labor and credit constraints. Assuming that a farmer i uses traditional X inputs to produce single or multiple conventional Y outputs, a production function can be written to represent a particular technology: $Y_i = f(x_i)$, where $f(x_i)$ is a production frontier. On the frontier, the farmer produces the maximum output for a given set of traditional inputs or uses the minimum set of traditional inputs to produce a given level of output. In standard microeconomic theory, there is no inefficiency in the economy, implying that all production functions are optimal and all farmers produce at the frontier. However, if markets are imperfect, farmers' yields can be pulled below the production frontier.

Consider now the environmental pollution of the agricultural production. Conventionally, environmental damage can be modeled as undesirable outputs (Cuesta et al., 2009). However in our case, we cannot apply this method since we have no precise data regarding environmental damage such as water or air pollution related to agricultural production. Alternatively, we focus on nitrogen as the most important source of environmental pollution, which is appropriate in the Chinese agriculture environment. This environmentally detrimental input can be introduced in the function production. To be efficient, a farmer needs to maximize his conventional yield with the environmentally detrimental input, i.e. nitrogen, as well as with other conventional inputs (X).

Within this framework, we follow Reinhard et al. (1999) by defining environmental efficiency as the ratio of minimum feasibility to the observed use of the environmentally detrimental input, conditional to observed levels of output and conventional inputs[8]. This can be formulated by the following non–radial input–oriented measure:

$$EE_i(x, y) = [\min \theta : F(x_i, \theta Z_i) \geq y_i], \tag{3.1}$$

where the variable y_i is the observed output for farmer i, produced using X_i of the conventional inputs and Z_i of the environmentally detrimental input. $F(.)$ is the best practise frontier with X and Z.

Following the method developed by Reinhard et al. (1999), environmental efficiency can be calculated using a standard translog production function as follows (Christensen et al., 1971)[9]:

$$\begin{aligned} ln(Y_{i,t}) = \beta_0 + \sum_{j=1}^{m} \beta_j ln(X_{ij,t}) + \beta_z ln(Z_{i,t}) + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \beta_{jk} ln(X_{ji,t}) ln(X_{ki,t}) \\ + \frac{1}{2} \sum_{j=1}^{m} \beta_{jz} ln(X_{ji,t}) ln(Z_{i,t}) + \frac{1}{2} \beta_{zz} ln(Z_{i,t})^2 - U_{i,t} + V_{i,t}, \end{aligned} \tag{3.2}$$

where $i = 1, \ldots, n$ is the plot unit observations and $t = 1, \ldots, T$ is the number of periods; $j, k = 1, 2, \ldots, m$ is the applied traditional inputs; $ln(Y_{i,t})$ is the logarithm of the output of plot i; $ln(X_{ij,t})$ is the logarithm of the j^{th} traditional input applied on the i^{th} plot; $ln(Z_{i,t})$ is the logarithm of the environmental detrimental input applied; and β_j, β_z, β_{jk}, β_{jz} and β_{zz} are parameters to be estimated[10]. The logarithm of the output of a technically efficient producer $Y^F_{i,t}$ with $X_{i,t}$ and $Z_{i,t}$ can be obtained by setting $U_{i,t} = 0$ in Equation 3.2. However, the logarithm of the output of an environmentally efficient producer $Y_{i,t}$ with $X_{i,t}$ and $Z_{i,t}$ is obtained by replacing $Z_{i,t}$ by $Z^F_{i,t}$, where $Z^F_{i,t} = EE_{i,t} * Z_{i,t}$, and setting $U_{i,t} = 0$ in Equation 3.2 as follows

[8]Environmental efficiency is thus an input–oriented measure, i.e., less environmental detrimental input with the same output and conventional inputs.

[9]We use a negative sign in order to show that the term $-U_{i,t}$ represents the difference between the most efficient farm (on the frontier) and the observed farm.

[10]Similarity conditions are imposed, i.e., $\beta_{jk} = \beta_{kj}$. Moreover, the production frontier requires monotonicity (first derivatives, i.e., elasticities between 0 and 1 with respect to all inputs) and concavity (negative second derivatives). These assumptions should be checked *a posteriori* by using the estimated parameters for each data point.

$$
\begin{aligned}
ln(Y_{i,t}) = \beta_0 + \sum_{j=1}^{m}\beta_j ln(X_{ij,t}) + \beta_z ln(Z^F_{i,t}) + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{m}\beta_{jk} ln(X_{ji,t}) ln(X_{ki,t}) \\
+ \frac{1}{2}\sum_{j=1}^{m}\beta_{jz} ln(X_{ji,t}) ln(Z^F_{i,t}) + \frac{1}{2}\beta_{zz} ln(Z^F_{i,t})^2 + V_{i,t}.
\end{aligned}
\tag{3.3}
$$

The logarithm of EE ($lnEE_{i,t} = lnZ^F_{i,t} - lnZ_{i,t}$) can now be calculated by setting Equations 3.2 and 3.3 equal as follows:

$$
\frac{1}{2}\beta_{zz}(lnEE_{i,t})^2 + (lnEE_{i,t})[\beta_z + \sum_{j=1}^{m}\beta_{jz} lnX_{ij,t} + \beta_{zz} lnZ_{i,t}] + U_{i,t}. = 0 \tag{3.4}
$$

By solving Equation3.4, we obtain:

$$
\begin{aligned}
& lnEE_{i,t} \\
& = \left[- \left(\overbrace{\beta_z + \sum_{j=1}^{m}\beta_{jz} lnX_{ij,t} + \beta_{zz} lnZ_{i,t}}^{A} \right) \right. \\
& \left. \pm \left\{ \left(\overbrace{\beta_z + \sum_{j=1}^{m}\beta_{jz} lnX_{ij,t} + \beta_{zz} lnZ_{i,t}}^{B} \right) - 2\beta_{zz} U_{i,t} \right\}^{0.5} \right] / \beta_{zz}
\end{aligned}
\tag{3.5}
$$

As mentioned by Reinhard et al. (1999), the output-oriented efficiency is estimated econometrically whereas environmental efficiency (Eq. 3.4) is calculated from parameter estimates (β_z and β_{zz}) and the estimated error component ($U_{i,t}$). Since a technically efficient farm ($U_{i,t} = 0$) is necessarily environmentally efficient ($lnEE_{i,t} = 0$). The "$+\sqrt{}$" must be used[11].

In our case of paddy rice production, three traditional inputs and one environment detrimental input are identified for the production function. The final stochastic model in the translog case is as follows:

$$
\begin{aligned}
Yield_{i,t} = \beta_0 + \beta_1.L_{i,t} + \beta_2.C_{i,t} + \beta_3.W_{i,t} + \beta_4.N_{i,t} + \beta_5.L^2_{i,t} + \beta_6.C^2_{i,t} + \beta_7.W^2_{i,t} + \beta_8.N^2_{i,t} + \beta_9.L_{i,t} \\
* C_{i,t} + \beta_{10}.L_{i,t} * N_{i,t} + \beta_{11}.L_{i,t} * W_{i,t} + \beta_{12}.C_{i,t} * W_{i,t} + \beta_{13}.C_{i,t} * N_{i,t} + \beta_{14}.N_{i,t} * \beta_{15}.W_{i,t} + Seed \\
+ Season - U_{i,t} + V_{i,t}.
\end{aligned}
\tag{3.6}
$$

Here the output is the yield of raw rice. The three traditional inputs are the labor (L), capital (C) and water (W), and the environment detrimental input is the pure nitrogen input (N) derived from both organic and chemical sources. All output and inputs are normalized by the plot area. Traditionally, farmers use different seeds in different seasons according to climate, we need to control for this in the equation with *Season* as a dummy fixing one of the five

[11] The sign in front of term B should necessarily be positive. Thus, if $U_{i,t} = 0$, then $lnEE_{i,t} = 0$.

seasons and *Seed* as a dummy for different seed species (see Tables 3.3 and 3.11 for descriptive statistics, and Table 4.6 for description and definition of variables). The inefficiency term is allowed to be time–variant following the Battese–Coelli parametrization of time-effects (Battese and Coelli, 1992). Therefore, the maximum likelihood estimator is appropriate to estimate technical efficiency, which is modeled as a truncated-normal random variable multiplied by a specific function of time[12].

One fundamental question underlying the standard model above is whether organic and conventional farming share similar production technology. In other words, should we model these two types of production processes with a single production function? Conventionally, one may expect that the organic standards and chemical input constraints will significantly change the production process. If this is the case, a single production function modelling may yield biased technical efficiency, and thus biased environmental efficiency. It is therefore necessary to control for technology heterogeneity in the production function or apply the meta–frontiers analysis (Battese and Rao, 2002; Battese et al., 2004; O'donnell et al., 2008).

However, we also have good reason to believe that the technology of organic and conventional farming may be similar in small and undeveloped rural areas, since poor farmers face a similar environment and cannot easily improve their production means by simply switching to organic farming during such a short time. The major difference between organic and conventional farming is reflected by the amount of inputs which is modelled by the translog production function. In other words, organic farming would not directly but rather indirectly influence the productivity through the efficiency terms (i.e., TE and EE). If this is the case, a two-stage analysis is appropriate (Battese and Coelli, 1995). Therefore, to ensure the relevance of technical efficiency from the beginning, we will need to perform a preliminary statistical test to determine the right specification of our production function as follows:

$$\begin{aligned} Yield_{i,t} &= \beta_0 + \beta_1.L_{i,t} + \beta_2.C_{i,t} + \beta_3.W_{i,t} + \beta_4.N_{i,t} + \beta_5.L^2_{i,t} + \beta_6.C^2_{i,t} + \beta_7.W^2_{i,t} + \beta_8.N^2_{i,t} \\ &+ \beta_9.L_{i,t} * C_{i,t} + \beta_{10}.L_{i,t} * N_{i,t} + \beta_{11}.L_{i,t} * W_{i,t} + \beta_{12}.C_{i,t} * W_{i,t} + \beta_{13}.C_{i,t} * N_{i,t} + \beta_{14}.N_{i,t} \\ &* W_{i,t} + \beta_{15}.Organic_{i,t} + Season + Seed - U_{i,t} + V_{i,t} \end{aligned} \tag{3.7}$$

In equation 3.7, a dummy *Organic*, stating if the plot is under organic farming, is appended in the standard production function to capture any potential "technology gap" between two technologies. Moreover, one may suspect that organic farming will also change the marginal contribution to output of each input. We thus append organic interactive terms with all inputs as in the following equation 3.8:

$$\begin{aligned} Yield_{i,t} &= \beta_0 + \beta_1.L_{i,t} + \beta_2.C_{i,t} + \beta_3.W_{i,t} + \beta_4.N_{i,t} + \beta_5.L^2_{i,t} + \beta_6.C^2_{i,t} + \beta_7.W^2_{i,t} + \beta_8.N^2_{i,t} \\ &+ \beta_9.L_{i,t} * C_{i,t} + \beta_{10}.L_{i,t} * N_{i,t} + \beta_{11}.L_{i,t} * W_{i,t} + \beta_{12}.C_{i,t} * W_{i,t} + \beta_{13}.C_{i,t} * N_{i,t} + \beta_{14}.N_{i,t} \\ &* W_{i,t} + \beta_{15}.Organic_{i,t} + \beta_{16}.Organic_{i,t} * L_{i,t} + \beta_{17}.Organic_{i,t} * C_{i,t} + \beta_{18}.Organic_{i,t} * \\ & W_{i,t} + \beta_{19}.Organic_{i,t} * N_{i,t} + Season + Seed - U_{i,t} + V_{i,t} \end{aligned} \tag{3.8}$$

The hypothesis of the existence of a "technology gap" will be verified by checking the joint significance of coefficients between the organic intercept and slope shifters (i.e., β_{15}–β_{19}).

Moreover, the endogeneity problem of organic farming can be addressed in this approach. In our case, the adoption of organic farming and agricultural output could be conjointly determined by some omitted environmental and personal factors (e.g., soil quality and farmer ability).

[12] Estimations are made using Stata 11 and the command *xtfrontier*.

These omitted variables may bias the coefficients as well as the significance of the variables associated to organic farming (additive and interaction terms). To deal with this issue, we run a within estimation which eliminates the bias due to all time-invariant factors. To get rid of any potential time-variant factors, we will perform a within-2SLS estimation and compare the results with that of the within estimation.

In our dataset, we have two available instruments which are (1) the presence of chemical fertilizer pollution near the plot (Pollution) and (2) the geographical distance from farmer's house to the plot (Distance). On one hand, the presence of chemical fertilizer pollution near the plot will render organic farming non credible and thus discourage this practice. On the other hand, organic farming requires harder work due to transport and application of organic compost and manure so that long distance from house to plot will thus discourage organic farming[13]. The validity of these instruments is tested by the Sargan over-identification test whereas their power is analysed by both the Shea partial R2 and the F statistics of excluded instruments. According to the result of these tests, we determine the correct specification of the production function. We can then derive technical efficiency and calculate environmental efficiency using the Formula 3.5.

3.3.2 Estimating the effect of organic farming on environmental efficiency

The second step of the analysis consists of comparing organic farming and conventional farming in terms of environmental efficiency, which is calculated from the first stage. To this end, we regress a simple econometric model as follows:

$$EE_{i,t} = \gamma_0 + \gamma_1 Organic_{i,t} + \gamma_2 Age_{i,t} + \gamma_3 Sex_{i,t} + \gamma_4 Educ_{i,t} + \varepsilon_{i,t}. \tag{3.9}$$

Equation 4.6 represents the relationship between environmental efficiency and organic farming. The coefficient γ_1 before the dummy variable *Organic* captures the difference of environmental efficiency between organic and conventional farming. Since environmental efficiency is a measurement of managerial performance which could depend on farmer characteristics, we control for major observable characteristics such as age, sex and education level of the plot owner in the model. Once again, to deal with the endogeneity of organic farming, a Within estimator is used to control for unobserved and time–invariant individual effects. For time-variant effects, we make use of the two instruments used in the first stage to test the similarity of the production technology between organic and conventional farming. As such, the presence of a neighbor's chemical fertilizer pollution and the geographical distance from the plot are used and combined with the fixed effect to perform a Within-2SLS estimation.

According to agronomic experimentation in field, the productivity of organic farming is heterogenous on various levels of nitrogen application. This observation is supported by another study stating that the yield of organic farming is less sensitive to nitrogen over certain critical levels (Kirchmann and Ryan, 2004). Should this be the case for environmental efficiency?

We explore the heterogeneity in environmental efficiency scores of organic farming on different nitrogen levels to derive more precise understanding. Given the potential endogeneity of nitrogen input, we could not introduce this variable and its interaction term (crossed with organic) into the model directly. Alternatively, we split the total sample into three size-equal

[13] Note that in a small village like Sancha, few machines are used for the transport and application of fertilizer.

sub–samples according to three critical levels of nitrogen application: (1) a high sub–sample which contains one third of the observations under which the level of nitrogen is the highest (ln N > 3.42); (2) a low sub–sample of one third of the observations under which the level of nitrogen is the lowest (ln N < 3.20); (3) a medium sub–sample of one third of the observations between the two levels (ln N between 3.20 and 3.42). Equation 4.6 is then estimated with respect to each of the three sub–samples. We note that this alternative solution is not perfect given that we can only observe a heterogenous correlation between environmental efficiency and organic farming rather than a causal effect.

Also, the effect of organic farming on environmental efficiency can be due to the level of training received by organic farmers. As mentioned in Section 2, newly converted farmers in Sancha village tend to use more nitrogen due to their uncertainty and lack of training. Newly converted farmers can thus demonstrate very low environmental efficiency because they are less trained and have little experience about organic farming. With our dataset, we can test if trained farmers, i.e., those who participated in the early organic farming experimentation in 2005, are more environmentally efficient than newly converted farmers. With the name list provided by the NGO, we are able to identify households who have participated in the experimentation and converted to organic farming since then. We thus redo the estimation of equation 4.6 with the sample of trained farmers.

We can test the explanation and the robustness of the heterogenous effect of organic farming on environmental efficiency according to nitrogen use by focusing on time. As mentioned in Section 2, the development of the organic project in Sancha village allows us to explore the variation of environmental efficiency over time. Promoted by the PCD, the organic project in the village has scaled up since 2009. Along with this scaling up, a boost of nitrogen use has been observed in organic farming. Intuitively, if the heterogenous effect exists, the environmental efficiency of organic farming may also be different before and after 2009. To this effect, we estimate the following equation:

$$\begin{aligned} EE_{i,t} = {} & \alpha_0 + \alpha_1 Organic_{i,t} + \alpha_2 2009_{i,t} + \alpha_3 2009 * Organic_{i,t} + \alpha_4 Age_{i,t} + \alpha_5 Sex_{i,t} \\ & + \alpha_6 Educ_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{3.10}$$

where the variable 2009 is a dummy of 1 if the season is in 2009 or after, and 0 otherwise (before 2009). The variable $2009 * Organic$ is an interaction term which captures the difference of organic effects before and after 2009. We control for farmer's age, sex and education level as in Equation 4.6. For the estimation of the model, the within and within-2SLS estimators are applied to correct for the endogeneity of organic farming and obtain consistent estimates.

3.4 Data and descriptive statistics

The data used for this study derived from a detailed survey conducted in Sancha village. For the purpose of comparative study, two plots (one organic and one conventional) were randomly selected for every active farmer from their reported paddy fields, and information about the rice production was then collected on the basis of the plot[14]. To ensure the reliability of organic practices reported by farmers, we also checked the answers against the records of the PCD. Inconsistent answers were dropped from the dataset. Information was collected for the past five consecutive crops seasons (from 2008 to first half of 2010) with respect to output and inputs

[14]Farmers with no organic plots were asked to give information on two conventional plots.

used on the plot.

The output consists of raw rice yield reported by farmers and expressed as kg per mu. Labor, capital and water are identified as three major conventional inputs, and the pure nitrogen is considered as the unique environmentally detrimental input for paddy rice production. For labor use, we asked farmers for labor time spent on each segment of a given rice production cycle such as soil plowing, plant setting, composting, fertilizer application, weed and pest control and harvesting. The final labor use is the sum of all segments and measured as hours per mu. The measure of capital refers to financial expenditures on machine use during the entire production cycle and is measured as yuan per mu. A measure of water use is introduced in the production function given that water is necessary for paddy rice production. However, this is also quite difficult to quantify. Given the lack of irrigation infrastructure, water consumption is expected to be constrained by water availability to the plot. We hereby construct a proxy variable, namely the index of water availability, which relies on average rain fall and mouse activity on the plot as observed by farmers.

The calculation of pure nitrogen is derived from the experimentation data of nitrogen content provided by local agronomists and farmers' self–reporting of nutrient inputs (e.g., quantity of chemical fertilizers, animal manure and compost, etc.). The calculation is the same as presented in Section 2 and expressed as kg per mu.

For other explanatory variables, socio–economic characteristics of households were collected. These characteristics include the age, sex and education level of the pot owner. We also collected information on plot characteristics such as area, geographical distance and nearby presence of fertilizer pollution spots. Table 3.3 gives descriptive statistics of the database and a summary of variable definitions can be found in Table 4.6 in the Tables and figures.

Table 3.3: Descriptive statistics by type of farming

	Total(1,012)		Organic Plot(345)		Conv Plot(667)		Equality test
	Mean	Sd	Mean	Sd	Mean	Sd	P-value
Yield (kg/mu)	342.16	(94.46)	336.49	(88.15)	345.09	(97.5)	0.17
Labor (h/mu)	129.81	(54.01)	156.33	(55.29)	116.09	(47.92)	0
N (kg/mu)	14.13	(3.96)	14.42	(4.03)	13.97	(3.93)	0.08
Capital (yuan/mu)	74.17	(52.21)	76.53	(51.31)	72.95	(52.67)	0.3
Water (1-3)	2.51	(0.65)	2.56	(0.67)	2.49	(0.64)	0.14
Age	54.59	(12.59)	53.42	(12.47)	55.19	(12.62)	0.03
Sex	0.61	(0.49)	0.68	(0.47)	0.57	(0.5)	0
Education	3.64	(3.3)	3.79	(3.51)	3.56	(3.19)	0.29
Distance (1-4)	1.91	(0.87)	1.57	(0.65)	2.09	(0.91)	0
Pollution (1/0)	0.74	(0.44)	0.34	(0.48)	0.95	(0.22)	0

Note: For all tests of means, the null hypothesis is that the means are equal against a two–sided alternative. The confidence level is at 5%.

From the descriptive statistics, we note that organic farming is more labor intensive than conventional farming, which is explained by the additional work of compost fabrication and transportation, as well as farm management. This abundant and hard work seems to discourage male and more aged farmers to produce organic rice in the village. Finally, the influence of geographical distance and neighbor fertilizer pollution is significant for the choice of organic farming. In the following section, we will present the estimated results and the calculated environmental efficiency from the SFA as well as the estimated results regarding the effect of organic farming on environmental efficiency.

3.5 Results and discussion

3.5.1 Technology gap and specification of SFA model

Table 3.4: Specification of SFA model

Dependent variable	Rice yield				
	Specification 1	Specification 2		Specification 3	
	(1)	(2)	(3)	(4)	(5)
Estimator	Within	Within	Within-2SLS	Within	Within-2SLS
Labor	2.271**	2.276**	2.309**	1.298	2.550
	(0.925)	(0.926)	(1.015)	(0.98)	(1.695)
Capital	1.616***	1.616***	1.616***	1.695***	1.714***
	(0.396)	(0.399)	(0.347)	(0.398)	(0.459)
Water	0.843	0.848	0.874	0.917	1.689*
	(0.599)	(0.604)	(0.616)	(0.571)	(0.923)
N	0.275	0.287	0.358	0.573	0.398
	(0.973)	(0.982)	(0.746)	(0.993)	(1.082)
Labor squared	-.208**	-.206**	-.191*	-.072	-.237
	(0.096)	(0.097)	(0.099)	(0.111)	(0.218)
Capital squared	-.156***	-.155***	-.148***	-.158***	-.115***
	(0.034)	(0.034)	(0.03)	(0.033)	(0.039)
Water squared	0.1	0.099	0.094	0.081	0.045
	(0.066)	(0.065)	(0.069)	(0.065)	(0.107)
N squared	0.017	0.015	0.006	-.002	-.075
	(0.103)	(0.104)	(0.09)	(0.095)	(0.124)
Labor*Capital	-.085	-.086	-.093*	-.109*	-.145*
	(0.058)	(0.057)	(0.048)	(0.064)	(0.081)
Labor*Water	-.100	-.100	-.099	-.100	-.231
	(0.094)	(0.095)	(0.095)	(0.09)	(0.154)
Labor*N	-.006	-.007	-.013	-.046	0.171
	(0.168)	(0.168)	(0.138)	(0.181)	(0.239)
Capital*Water	0.04	0.04	0.037	0.044	0.037
	(0.046)	(0.046)	(0.045)	(0.046)	(0.058)
Capital*N	0.035	0.034	0.03	0.046	-.013
	(0.055)	(0.055)	(0.048)	(0.053)	(0.07)
Water*N	-.169	-.170	-.173*	-.185*	-.241**
	(0.116)	(0.116)	(0.101)	(0.107)	(0.123)
Organic		-.016	-.112	0.651	-.013
		(0.043)	(0.077)	(0.534)	(1.126)
Organic*Labor				-.150	0.21
				(0.098)	(0.28)
Organic*Capital				0.057	0.094
				(0.038)	(0.091)
Organic*Water				-.023	0.196
				(0.051)	(0.168)
Organic*N				-.050	-.565
				(0.06)	(0.371)
Observations	1,012	1,012	1,012	1,012	1,012
Plots	203	203	203	203	203
Adjusted R2	0.456	0.455	0.306	0.465	0.231
F statistic	23.656	22.469	22.23	20.287	15.081
RMSE	0.135	0.135	0.15	0.133	0.179
Hansen statistic					6.964
Hansen P-value					0.138

Note: Robust standard errors in parentheses. 5 seasons and 7 seeds are controlled for. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%. The Hansen statistic is not reported for column 3 since there is only one IV (distance is time invariant and dropped).

The first step is to test the hypothesis of "technology gap" between organic and conventional farming to determine the best specification of the SFA model. Three specifications (i.e., without controlling for organic farming, with organic additive intercept, and with organic additive intercept and interaction terms with each input) are thus estimated by the within and within-2SLS estimators (see Table 3.12 in the Tables and figures for the estimated results of the instrumentation equation). A comparison of estimated results are presented in Table 3.4.

In column 1 of Table 3.4, we estimate the standard SFA model and report it as a benchmark. One can note, in columns 2 and 3, that the inclusion of the organic variable in the model does not change many of the coefficients, and the organic intercept is also not significant. When the organic interaction terms are included in the model, the labor loses its significance. This is probably due to its correlation with the interaction term of $Organic * Labor$. To check the hypothesis of a "technology gap", we test the restrictions that the organic dummy and interaction terms are jointly equal to zero. The chi-squared statistic from a Wald test is 5.09 with an associated p-value of 0.405. Thus we cannot reject the null hypothesis that the organic intercept and slope shifters are jointly equal to 0 at conventional significance level. Put another way, the "technology gap" between organic and conventional farming is not significant in our case.

This result is in contrast with other studies on technical efficiency of organic farming in developed countries (Mayen et al., 2010). It is however reasonable in the context of developing countries. In the literature of organic farming, emerging evidence has shown that organic farming has similar productivity to that of conventional farming (Pretty and Ball, 2001; Badgley et al., 2007). Thus, our test provides empirical evidence that converting to organic farming will not jeopardize the productivity of paddy rice production in the Chinese smallholder environment. On the basis of this result, we adopt the standard specification of the SFA model (i.e., specification without controlling for organic farming) and estimate it with the maximum likelihood estimator in the next step.

3.5.2 Estimation of the SFA model

In this section, we check the relevance of the SFA model with our dataset. Here we specify the time-variant inefficiency as Battese and Coelli (1992). The inputs marginal productivity and elasticities are reported in Table 4.2.

Firstly, we check the theoretical consistency of our estimated efficiency model by verifying that the marginal productivity of inputs are positive. If this theoretical criterion is met, then the obtained efficiency estimates can be considered as consistent with microeconomics theory. As the coefficients of the translog functional form do not allow for direct interpretation of the magnitude and significance of any inputs, we compute the output elasticities for all inputs at the sample mean and median and report them in column (3) and column(4)

In our sample, the paddy rice production in Sancha village depends more strongly on nitrogen (0.36) and water (0.13) at the sample mean. This suggests that the yield of rice production is most likely relative to nitrogen and water use. However, the marginal productivity of labor appears to be negative (-0.019) at the sample mean. This result seems acceptable within the context of Chinese agriculture. According to other studies, surplus labor may exist in remote areas (Wan and Cheng, 2001; Fan et al., 2003). The over–use of labor inputs implies that the marginal productivity of labor must be very low, even negative in some cases (Tian and Wan, 2000; Tan et al., 2010; Chen et al., 2006). Finally, our results ensure that the returns to scale at sample mean and the sample median are both positive.

Within the framework of the translog stochastic production frontier, we predict technical efficiency scores and thereby calculate environmental efficiency scores (see Table 3.11 regarding descriptive statistics of both technical and environmental efficiency). Technical efficiency is significant in our sample with a mean value of 0.73, ranging from 0.33 to 0.98. The score suggests that most farmers, both conventional and organic, have sufficiently mastered the technology to produce satisfactory yield. However, when looking into the environmental efficiency scores, the mean value is only 0.45, ranging from 0.08 to 0.96. The standard error of environmental efficiency is higher (0.18) than that of technical efficiency (0.12). This result suggests that most farmers are not environmentally efficient rather that technical efficiency cannot guarantee environmental efficiency. Should converting to organic farming help to improve environmental efficiency? We now turn to the second step of our analysis to investigate this question.

Table 3.5: Stochastic production frontier model

Dependent variable	rice yield			
	Marginal productivity		input elasticities	
	(1)	(2)	(3)	(4)
Variables	Coefficient estimate	Standard error	Sample mean	Sample median
Labor	0.844*	0.467	-0.019	-0.044
Capital	1.328***	0.183	0.083	0.128
Water	1.030***	0.388	0.132	0.159
N	0.216	0.447	0.360	0.321
Labor squared	-.086*	0.045		
Capital squared	-.164***	0.016		
Water squared	0.077	0.058		
N squared	-.022	0.067		
Labor*Capital	-.018	0.035		
Labor*Water	-.120*	0.062		
Labor*N	0.043	0.068		
Capital*Water	0.0007	0.031		
Capital*N	0.051	0.036		
Water*N	-.142*	0.073		
Observations	1,012			
Plots	203			
χ^2 statistic	761.16			
Log-likelihood	259.352			
Sig-u (TE.)	0.212			
Sig-v (errors.)	0.151			
$H_0 : \mu = 0$	0.270***			
$H_0 : \eta = 0$	0.034*			
$H_0 : \gamma = 0$	0.683**			

Estimation method: Maximum likelihood estimator with time-variant TE. $H_0 : \mu = 0$, $H_0 : \eta = 0$ and $H_0 : \gamma = 0$ report alternatively the null hypotheses that the technical inefficiency effects (1) have a half-normal distribution, (2) are time invariant and (3) present in the model. 5 seasons and 7 seeds are controlled for. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

3.5.3 Environmental efficiency of organic farming

Table 3.6 presents the estimation results of equation 3.7. As discussed in Section 3.2, we explore the heterogenous effect of organic farming on different levels of nitrogen application by looking into three equal sub-samples. To save room, we only report results by the within-2SLS estimator and its first stage regression. The result of the within estimation are found in Table 3.13 in the Tables and figures.

Table 3.6: Environmental efficiency of organic farming

	First stage				Second stage			
Dependent variable	Organic				Environmental efficiency			
	(1) Total	(2) High	(3) Med	(4) Low	(5) Total	(6) High	(7) Med	(8) Low
POLLUTION	-.620*** (0.068)	-.577*** (0.149)	-.417*** (0.142)	-.657*** (0.115)				
ORGANIC					0.011 (0.007)	-.012 (0.019)	0.029* (0.015)	0.022* (0.013)
AGE	0.064*** (0.013)	-.005 (0.015)	0.055*** (0.02)	0.038** (0.018)	0.016*** (0.001)	0.019*** (0.002)	0.017*** (0.002)	0.013*** (0.003)
Observations	1,012	338	340	334	1,012	338	340	334
Plots	203	117	146	130	203	117	146	130
R^2	0.404	0.393	0.267	0.462	0.250	0.269	0.389	0.149
F statistic	72.528	7.538	9.004	21.398	122.885	47.09	61.515	16.684
RMSE	0.183	0.111	0.123	0.126	0.026	0.025	0.020	0.026

Note: Robust standard errors in parentheses. Distance, sex and education are dropped given their time invariant nature. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

At first glance, the difference of environmental efficiency between organic and conventional farming is non-significant (Col.5). However, the picture is not the same for all sub-samples. At low and medium levels of nitrogen (i.e., application rate below 15.29 kg per mu), the sign of organic farming is positive at 10 percent statistical significance (Col.7 and 8). This means that for plots with medium and low nitrogen, converting to organic farming does minimize the nitrogen use at the actual output level. The advantage of organic farming is thus obvious compared to conventional farming. Nevertheless, this performance of organic farming does not sustain a high nitrogen level (i.e., application rate above 15.29 kg per mu). The effect of organic farming becomes negative but non–significant (Col.6). In other words, for plots using high levels of nitrogen, converting to organic farming does not minimize the nitrogen application and thus does not allow for improvement in environmental efficiency.

This result is not surprising. In Europe, for instance, at high nitrogen application levels, agronomist experiments also provide evidence showing that the nitrogen-use efficiency of organic farming systems is indeed lower than conventional farming systems (Kirchmann and Ryan, 2004). This result suggests that in a developing country like China, one should interpret the impact of organic farming with caution. Rapid conversion to organic farming does not necessarily mean the reduction of nitrogen use. At high levels of nitrogen input (usually for the case of industrialized production), conversion to organic farming does not improve environmental efficiency or resolve agricultural pollution problems due to nitrogen overuse.

3.5.4 Robustness check

How to explain the decreasing performance of organic farming at high nitrogen levels? As mentioned in Section 2, newly converted farmers in Sancha village tend to use more nitrogen due to their uncertainty and lack of training. Meanwhile, the experience and field management capacity of farmers could also determine their environmental efficiency. Intuitively, the behaviors of newly converted farmers may probably explain the reduction of environmental efficiency for organic farming at high nitrogen levels. With our dataset, we can test this explanation by focusing on environmental efficiency of trained farmers, i.e., those who participated in the early organic farming experimentation in 2005. With the name list provided by the NGO, we are able to identify households who have participated in the experimentation and converted to organic farming since then. We redo the same estimation with observations of these households and check the results again. If the results turn out to be positive and significant for all sub-samples, we can then validate this explanation. We now turn to the within-2SLS estimation results in Table 3.7 (see the results of the within estimation in 3.14 in the Tables and figures).

Table 3.7: Environmental efficiency of trained organic farmers

Dependent variable	First stage Organic				Second stage Environmental efficiency			
	(1) Total	(2) High	(3) Med	(4) Low	(5) Total	(6) High	(7) Med	(8) Low
POLLUTION	-.635***	-.861***	-.533***	-.737***				
	(0.116)	(0.167)	(0.177)	(0.241)				
ORGANIC					0.016*	0.016*	0.032**	0.023***
					(0.009)	(0.008)	(0.015)	(0.007)
AGE	0.019	-.019	0.03	0.001	0.016***	0.016***	0.018***	0.016***
	(0.014)	(0.022)	(0.021)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
Observation	473	179	154	140	473	179	154	140
Plots	95	58	68	56	95	58	68	56
R^2	0.472	0.624	0.52	0.739	0.286	0.258	0.46	0.281
F statistic	18.56	13.435	7.126	8.364	75.374	33.907	33.962	56.502
RMSE	0.136	0.099	0.1	0.052	0.023	0.024	0.018	0.02

Note: Robust standard errors in parentheses. Distance, sex and education are dropped given their time invariant nature. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

As one can note in columns 5–8, with observations of trained farmers, we now find that organic farming is significantly superior to conventional farming in terms of environmental efficiency regardless of the nitrogen level. This result confirms our explanation and completes the story. Having received effective technical training and environmental education provided by the PCD, experienced farmers are indeed more conscious about the environmental problem and more respectful of the principles of organic farming. With effective training in farm management, they are able to minimize the use of external nitrogen rather than increasing it to maintain the output as done by newly converted farmers. From the environmental efficiency point of view, the organic farming conducted by trained farmers is more sustainable than that of newly converted farmers. Taken together, our results stress the importance of technical and agricultural extension service in the promotion of organic farming. Effective support such as farmer capacity building and environmental education are also necessary in guaranteeing the environmental efficiency of organic farming in its development. Without this support, organic farmers may use more organic nitrogen to compensate for the lack of chemical fertilizer and ignore the management of nitrogen. As a result, while maintaining the output, organic farming may fail to achieve its objective of environmental protection.

To check the robustness of our results, we explore the performance of organic farming over time. We recall that the boost of nitrogen input in organic farming is observed in the scale-up period from 2009 (see Table 3.2 in Section 2). As a consequence, a substantial number of newly converted organic farmers joined the organic farming project from 2009 which can explain the boost of nitrogen used to compensate a potential yield loss due to a lack of experience. We should thus find a negative effect of organic farming on environmental efficiency after 2009.

Table 3.8: Environmental efficiency of organic farming over time

	First stage				Second stage		
Dependent variable	Organic			2009*Organic	Environmental efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
POLLUTION	-.620***	-.609***	-.614***	0.053			
	(0.068)	(0.067)	(0.078)	(0.069)			
2009*POLLUTION			0.048	-.631***			
			(0.059)	(0.067)			
2009*DISTANCE			-.075***	-.104***			
			(0.024)	(0.029)			
ORGANIC					0.011	0.007	0.018**
					(0.007)	(0.007)	(0.008)
2009		0.075**	0.183***	1.023***		0.017***	0.02***
		(0.031)	(0.06)	(0.07)		(0.003)	(0.004)
2009*ORGANIC							-.012**
							(0.005)
AGE	0.064***	0.022	0.023	0.023	0.016***	0.007***	0.007***
	(0.013)	(0.019)	(0.018)	(0.018)	(0.001)	(0.002)	(0.002)
Observation	1,012	1,012	1,012	1,012	1,012	1,012	1,012
Plots	203	203	203	203	203	203	203
R^2	0.404	0.41	0.426	0.635	0.25	0.271	0.272
F statistic	72.528	48.956	30.748	138.877	122.885	98.137	73.363
RMSE	0.183	0.182	0.18	0.198	0.026	0.025	0.025
Hansen statistic							0.518
Hansen P-value							0.472

Note: Robust standard errors in parentheses. Distance, sex and education are dropped given their invariant variables. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.8 reports the environmental performance of organic farming before and after 2009 when the organic farming project scaled up. The results estimated by the within-2SLS estimator are presented and the results by the within estimator are found in Table 3.15 in the Tables and figures. In column 7, organic farming is found to have a positive and significant effect on environmental efficiency after controlling for both the turning point in the organic farming project, i.e., 2009, and plot fixed effects. However, the interaction term has a significant and negative effect. That is to say, before 2009, organic farming was more efficient than conventional farming in terms of environmental efficiency. However, after 2009, this environmental performance of organic farming significantly decreased. This result is in line with our previous findings and confirms the robustness of our result stating that newly converted organic farmers increased the use of external nutrients in an attempt to compensate for the potential yield loss they feared.

3.6 Concluding remark and discussions

In this chapter, we attempt to evaluate the sustainability of non-certified organic farming with respect to yield and external nitrogen utilization in the case of rice production in Sancha village. To this end, we estimate a classical SFA model and check the hypothesis of a "technology gap" between organic and conventional farming. Then we calculate the environmental efficiency scores for both systems from the estimated technical efficiency scores. We use these scores to measure the environmental performance (i.e., efficiency of nitrogen management) of smallholder farmers. This exercise is useful to provide insight about non–certified organic farming's environmental performance and to understand the condition for its sustainable development in smallholder environment. The data used for this exercise is derived from a plot-level household survey conducted in Sancha village where non-certified organic farming is rapidly expanding.

With this case study, we obtain several interesting results. First, conversion to organic farming does not necessarily reduce the rice yield if farmers can substitute chemical fertilizers with organic nutrients. There is no significant "technology gap" between organic and conventional farming in a smallholder environment. Second, nitrogen management is not always optimal in an organic system, especially for newly converted organic farmers who lack training. At high nitrogen application levels, organic farming has no advantage in terms of environmental efficiency. In other words, to maintain the yield, organic farming consumes the same quantity, and sometimes more, of environmentally detrimental nutrients than conventional farming in rural China.

The experience of Sancha village has critical policy implications for non-certified organic farming development in developing countries. By definition, organic farming is a kind of agricultural exploitation with long term objectives to preserve the environment. Its sustainability relies more on efficient nutrient cycling within the agro–ecosystem than on the external nutrient supply. The aim of nutrient application is thus to improve and enhance the fertility and resilience of soil, but not to feed the plants directly. Substitution of chemical fertilizer by organic nutrients is a first step but is not sufficient to achieve this goal. Just as argued by Stolze et al. (2000), the regulation of the use of inputs is the most important method to obtain environmental results from organic farming. Therefore, additional efforts such as technical support and environmental education are crucial in the development of organic farming.

In developing countries, driven by political and economic interests, governments often ignore this critical condition and promote organic farming solely through economic policies such as organic fertilizer subsidies. This economic policy seems effective as it reduces the cost of organic nutrients and encourages conversion in the short term. Nevertheless, it risks inducing rapid conversion and high organic nutrient application which can induce inexperienced farmers laking effective technical support to apply the same, or more, nutrients than conventional farmers in an attempt to maintain the yield. This policy is thus non sustainable in areas facing a shortage of organic nutrient supplies and nutrient surpluses in the soil. In light of growing trends that see governments seeking to expand and industrialize organic farming in developing countries, our study warns of the potential risk of rapid expansion, and highlights the need for regulation of nutrient application in developing countries.

In order to preserve the environmental efficiency of organic farming and develop it in a sustainable way, governments and development agencies need to provide more institutional support such as environmental education and technical training to accompany farmers during the conversion period. Otherwise, more strict regulation with respect to nutrient application is needed in the rapid expansion of organic farming in developing countries.

Tables and figures

Definition of variables and descriptive statistics

Table 3.9: Definition of variables

Variable Name	Definition and description
Organic	Farmer's self report organic status. It's a binary variable code "1" if the plot is under organic management. Code "0" otherwise.
Yield	The quantity of raw rice harvested from the plot at end of the season, the unit is "kg/mu".
Labor	Hours spent in paddy rice production on the plot. It is weighted by the age of farmer. The unit is "hours/mu".
N	The external Nitrogen input from organic source or inorganic source for the paddy rice production on the plot. The unit is "kg/mu".
Capital	Money spent for the rice production on the plot including the machinery, employment and seed cost. The unit is "yuan/mu".
Water	Index of water availability to the plot, range from 1 to 3. High index means good water availability.
Age	The age of the household head.
Sex	The Sex of the household head.
Education	Years of education of the household head.
Distance	The geographical distance from farmer's house to the plot. Evaluated by farmer in terms of minutes of walk. Range from 1 to 4.
Pollution	The presence of pollution from chemical fertilizer application nearby the plot: "1" for yes and "0" for no.
Seed	Seven different species of rice seeds cultivated by farmers during the 5 seasons coded from 1 to 7.

Table 3.10: Nitrogen content of paddy rice production in Sancha village

	Nitrogen content (g N/kg)	
	Organic farming	Conventional farming
Output: Raw rice	23	23
Inputs:		
Cow dung	3	3
Hen manure	10	10
Pig manure	6	6
Compost	15	.
Compound fertilizer	.	150
Urea Fertilizer	.	460

Source: agronomic experiment data provided by local agronomists.

Table 3.11: Descriptive Statistics

Variables	Mean	Standard deviation	Min	Max	♯ obs.
Log of rice output	6.487	(0.297)	4.472	7.313	1,012
Log of labor	4.781	(0.418)	3.348	5.825	1,012
Log of capital	4.044	(0.741)	1.322	5.58	1,012
Log of water	0.877	(0.326)	0	1.099	1,012
Log of N	3.302	(0.285)	2.298	4.234	1,012
Organic farming (=1)	0.341	(0.474)	0	1	1,012
Age in years	54.587	(12.588)	28	79	1,012
Sex (=1 if woman)	0.607	(0.489)	0	1	1,012
Education	3.639	(3.298)	0	12	1,012
Seed (from 0 to 6)	1.922	(2.526)	0	6	1,012
Technical efficiency	0.724	(0.122)	0.345	0.976	1,012
Environmental efficiency	0.45	(0.184)	0.082	0.962	1,012

Authors' calculation.

First–stage regressions results (IV)

Table 3.12: First-stage regression of Table 3.4

Dependent variable	(1) ORGANIC	(2) ORGANIC	(3) ORG*Labor	(4) ORG*Capital	(5) ORG*Water	(6) ORG*N
POLLUTION	-.332*** (0.057)	-.629 (0.859)	-1.302 (4.152)	-.985 (3.135)	-.296 (0.753)	-.016 (2.682)
Labor*POLLUTION		0.145 (0.152)	0.293 (0.736)	0.781 (0.573)	0.099 (0.139)	0.277 (0.479)
Capital*POLLUTION		0.012 (0.056)	0.117 (0.262)	-.552** (0.236)	0.036 (0.048)	-.009 (0.176)
Water*POLLUTION		-.116 (0.093)	-.511 (0.435)	-.385 (0.398)	-.643*** (0.081)	-.358 (0.276)
N*POLLUTION		-.100 (0.149)	-.497 (0.757)	-.457 (0.565)	-.033 (0.126)	-.595 (0.567)
Labor*DISTANCE		-.385*** (0.111)	-1.786*** (0.525)	-1.480*** (0.446)	-.235** (0.106)	-1.066*** (0.357)
Capital*DISTANCE		-.052 (0.032)	-.248* (0.146)	-.122 (0.141)	-.019 (0.033)	-.113 (0.105)
Water*DISTANCE		-.020 (0.031)	-.112 (0.149)	-.074 (0.121)	-.053 (0.057)	0.024 (0.118)
N*DISTANCE		0.157** (0.071)	0.67* (0.347)	0.558* (0.288)	0.107 (0.072)	0.399* (0.237)
Labor	0.791 (1.305)	0.869 (1.378)	-.268 (6.338)	3.507 (5.723)	2.317 (1.411)	2.274 (4.231)
Capital	0.148 (0.39)	0.263 (0.406)	0.938 (1.856)	-.134 (1.768)	0.148 (0.381)	0.501 (1.268)
Water	0.36 (0.849)	0.61 (0.786)	3.092 (3.507)	1.099 (3.545)	-.861 (0.743)	2.034 (2.470)
N	0.291 (1.117)	0.298 (1.182)	4.072 (6.039)	2.265 (4.917)	0.032 (0.99)	2.563 (4.084)
Labor squared	0.072 (0.134)	0.124 (0.144)	1.254* (0.692)	0.266 (0.593)	-.130 (0.149)	0.38 (0.455)
Capital squared	0.052* (0.028)	0.058** (0.026)	0.282** (0.123)	0.276** (0.115)	0.03 (0.024)	0.229** (0.089)
Water squared	-.010 (0.07)	0.016 (0.064)	0.033 (0.295)	0.171 (0.276)	-.031 (0.079)	-.040 (0.231)
N squared	-.027 (0.138)	-.076 (0.137)	-.453 (0.69)	-.484 (0.518)	-.075 (0.124)	-.403 (0.503)
Labor*Capital	-.063 (0.072)	-.072 (0.073)	-.302 (0.331)	0.116 (0.299)	-.045 (0.077)	-.198 (0.23)
Labor*Water	-.015 (0.104)	-.056 (0.094)	-.284 (0.417)	-.129 (0.446)	0.334*** (0.129)	-.195 (0.314)
Labor*N	-.034 (0.146)	-.012 (0.149)	-.470 (0.745)	0.067 (0.605)	0.019 (0.124)	0.079 (0.508)
Capital*Water	-.009 (0.042)	-.020 (0.042)	-.096 (0.197)	-.085 (0.181)	0.012 (0.048)	-.040 (0.129)
Capital*N	-.058 (0.069)	-.063 (0.068)	-.289 (0.325)	-.388 (0.252)	-.038 (0.058)	-.286 (0.243)
Water*N	-.074 (0.158)	-.043 (0.143)	-.209 (0.672)	0.042 (0.599)	0.055 (0.12)	-.207 (0.442)
Observations	1,012	1,012	1,012	1,012	1,012	1,012
Plots	203	203	203	203	203	203
R^2	0.651	0.669	0.684	0.702	0.705	0.64
F statistic	24.652	23.386	25.067	26.115	36.722	20.827
RMSE	0.142	0.138	0.666	0.564	0.136	0.476

Note: Robust standard errors in parentheses. 5 seasons and 7 seeds are controlled for. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%. Distance is dropped given its time invariant nature.

Within estimation results

Table 3.13: EE of organic farming over nitrogen levels

	(1) Total	(2) High	(3) Med	(4) Low
Dependent variable	Environmental efficiency			
ORGANIC	0.014***	-.001	0.023***	0.005
	(0.004)	(0.009)	(0.007)	(0.008)
AGE	0.016***	0.019***	0.018***	0.014***
	(0.001)	(0.002)	(0.002)	(0.003)
Observations	1,012	338	340	334
Plots	203	117	146	130
R^2	0.251	0.273	0.391	0.166
F statistic	114.003	39.711	73.311	15.129
RMSE	0.023	0.02	0.015	0.02

Note: Robust standard errors in parentheses. Sex and education are dropped given their time invariant nature. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.14: EE of experienced organic farming over nitrogen levels

	(1) Total	(2) High	(3) Med	(4) Low
Dependent variable	Environmental efficiency			
ORGANIC	0.017***	0.017***	0.021*	0.025***
	(0.005)	(0.005)	(0.011)	(0.005)
AGE	0.016***	0.016***	0.019***	0.015***
	(0.002)	(0.003)	(0.003)	(0.004)
Observations	473	179	154	140
Plots	95	58	68	56
R^2	0.286	0.258	0.467	0.281
F statistic	69.224	30.242	45.224	291.353
RMSE	0.021	0.02	0.013	0.016

Note: Robust standard errors in parentheses. Sex and education are dropped given their time invariant nature. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.15: EE of organic farming over time

	(1)	(2)	(3)
Dependent Variable	Environmental efficiency		
ORGANIC	0.014***	0.011***	0.016***
	(0.004)	(0.004)	(0.005)
Y		0.016***	0.018***
		(0.003)	(0.004)
DD			-.007*
			(0.004)
AGE	0.016***	0.007***	0.007***
	(0.001)	(0.002)	(0.002)
Observations	1,012	1,012	1,012
Plots	203	203	203
R^2	0.251	0.272	0.275
F statistic	114.003	98.133	73.827
RMSE	0.023	0.025	0.025

Note: Robust standard errors in parentheses. Sex and education are dropped given their time invariant nature. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Chapter 4

Case III: Is Participatory Social Learning a Performance Driver for Smallholder Farmers?

4.1 Introduction

Smallholder or family farming is the primary and most widespread form of agricultural production in developing countries. It is estimated that 500 million rural people in developing countries live on small farms (less than two hectares). The majority are undernourished people living in absolute poverty (Hazell et al., 2007). According to FAO's World Census of Agriculture, there are 193 million small farms in China, which represent more than 95 per cent of total farms (Swaminathan, 2013; Bélières et al., 2013). Given the special land tenure regime, the average farm size in China is under 0.5 hectare (Fan and Chan-Kang, 2005)[1].

This prevalent smallholder farming plays a critical role in the sustainable agricultural development. From a sociological perspective, smallholder farming ensures the social equity, poverty reduction and food security. It is essential for poor people with limited resources and their substantial livelihood depends on these small pieces of land (Hazell and Ramasamy, 1991; Greenland, 1997). From an economic perspective, smallholder farming may be more productive according to the studies supporting the inverse relationship between farm size and productivity (Sen, 1962; Feder et al., 1985; Heltberg, 1998; Raghbendra et al., 2000; Fan and Chan-Kang, 2005; Lipton, 2006). From an ecological perspective, smallholder farming is natural resource and bio–diversity conserving, which makes it more suitable and favorable for the development of environmentally sound and sustainable agricultural technologies for our green future (Altieri, 2002).

However, smallholder farming is facing challenges in the context of economic globalization and transition. For instance, along with the development of manufacturing sector, more and more smallholder farmers intend to move out of agriculture. In China, more than 150 million farmers have moved out to work in the city (Cai and Wang, 2008). Meanwhile, accelerating urbanization and attractive investment opportunities have opened up in agriculture, leading to large–scale investments and competition for land, e.g., rubber plantations in Cambodia, palm oil production in Indonesia, real estate exploitation in China. Moreover, the soaring price

[1] In China, the agricultural land is collectively owned. Under the Household Responsibility System (HRS), rural households have right to exploit arable land for a long period of 30 years. The size of land mainly depends on household size and composition.

of productive inputs, deterioration of agro–environment and threats of climate change make smallholder farming more vulnerable.

In recent years, it is increasingly acknowledged that smallholder farming should be revived in the development of sustainable agriculture. It is argued that smallholder farmers who get involved in the management of social-ecological systems may learn and therefore enhance their adaptive capacity through their involvement in decision making processes (Folke et al., 2005; Fazey et al., 2007). This process is known as social learning. In the influential work of Bandura (1977), social learning is defined as individual learning based on observation of others and their social interactions within a group, e.g. through imitation of role models. supported by the social learning theory, a number of farmer participatory development approaches have been put forward to get smallholder farmers involved in the sustainable agriculture in developing countries (Pretty, 1995; Desai and Potter, 2013). The raising literature of social learning and participatory development has critical implication for ongoing sustainable agriculture development, yet the empirical test of social learning remains rare. To our knowledge, few empirical study of the social learning exists in China.

To fill this blank, this chapter attempts to determine the effect of participatory social learning on smallholder farmers' economic and environmental performances in rural China. We have identified the Sancha village in southwest China where farmer participatory social learning was organized for organic paddy rice production. We conduct a household survey in the village and collect a plot level panel dataset for the empirical analysis. In terms of econometric methodology, we combine the Spatial Autoregressive (SAR) model with peer effect analysis to estimate the social learning effect within carefully defined learning group. Specifically, we purge confounding factors such as inputs contamination (i.e., nitrogen fertilizer) by using the technical efficiency and environmental efficiency as dependent variables of the model. With different efficiency terms, we test whether farmers learn to maximize their output (technical efficiency), or to minimize their nitrogen use (environmental efficiency). Finally, the estimation is applied within separated sub–samples of conventional and organic farming to test the technological constraints of social learning.

Our estimation results suggest that the effect of social learning is non significant among smallholder farmers in general case. This is mainly due to the heterogeneity of technology in smallholder system. In the case of organized organic farming, social learning is significant in improving farmers' technical efficiency, but not their environmental efficiency. In other words, farmers learn to maximize their output rather than to minimize nitrogen input. Based on these results, we conclude that social learning is effective in fostering smallholder farmers' performance for productive agriculture if it is well organized. However, for the goal of resource conservative agriculture, external supports such as extension service and environmental education are needed to guide smallholder farmers.

For the remainder of the chapter, Section 2 reviews the literature of social learning and smallholder sustainable agriculture. Section 3 describes the organization of social learning in the village. Section 4 explains the methodological framework of our analysis and the identification strategy. Section 5 gives details about our data and Section 6 discusses the main results. Section 7 provides policy implications and concludes.

4.2 A literature review of social learning and sustainable agricultural development

Environmentally–sound or ecological agriculture (e.g. organic farming, low-input agriculture and permaculture) has been promoted by governments and development agencies for sake of sustainable agricultural development during past decades (FAO, 2002; IFAD, 2002; WorldBank, 2009; Twarog, 2006). In contrast to conventional agriculture, ecological agriculture can generate outstanding environmental benefits and ecosystem services, e.g. reduction of soil erosion and pollution, improvement of soil fertility and bio diversity, and alleviation of dependence on chemical inputs (Swinton et al., 2007). Particularly, sustainable agriculture seems to be more profitable in developing countries given its features of low external–input and increasing yield albeit original low level (Stoop et al., 2002; Pretty et al., 2003).

A big challenge for development of the sustainable agriculture in developing countries remains to involve smallholder farmers. In response, new development initiatives such as Participatory Research and Development (PRD) and the Farmer Field Schools (FFS) have emerged to promote sustainable agriculture to smallholder farmers in developing countries (Braun et al., 2000; Godtland et al., 2004; Feder et al., 2004). These initiatives aim to introduce and adapt sustainable agriculture to local conditions by farmers' participatory field trial and then to diffuse successful experience through a social learning process (Pretty, 1995; Pretty and Uphoff, 2002). A growing body of studies have emerged recently to evaluate the impact of farmer participatory initiatives and understand the process of social learning (Godtland et al., 2004; Feder et al., 2004; Van den Berg and Jiggins, 2007).

In economics, the literature of social network analysis has opened a new perspective for more thorough understanding about farmers' social learning process (Romer, 1986; Lucas, 1988; Rogers, 1995). On the theory side, Besley and Case (1994) develop a dynamic model of learning to study farmers' adoption decision of new technology. In this model, the uncertainty about the profitability is a major concern for farmers' adoption of new technology. In a Bayesian learning process, farmers can learn from their own experience as well as others' behavior about the true profitability and update their own behavior. In a repeated equilibrium, interaction between farmers is necessary provided the information is a public good. Using this model, one can predict the diffusion path of the new technology.

Alternatively, Foster and Rosenzweig (1995) adapt a "target-input" model to explain farmers' learning about the optimal use of inputs with the new technology (Wilson, 1975; Jovanovic and Nyarko, 1994). In the setting of "target-input" model, the profitability of new technology is increasing with the accumulation of knowledge observed from neighbors. The accumulated knowledge allows farmers to learn about the target input rate or the optimal input level to merit adoption. Therefore, they argue that learning about input productivity is as important as profitability in the diffusion of new technology, while identification of social learning using information of input productivity or its rewards is more accurate than adoption behavior.

The "target-input" model is useful to explain the social learning based on "rule-of-thumb" learning behavior (Conley and Udry, 2001)[2]. In situations where agent cannot observe his neighbors' experience perfectly, or where neighbors' performance is essentially determined by unobserved individual characteristics and conditions, social learning may be weak. In other words, agents learn from similar neighbors only (Ellison and Fudenberg, 1993). In a more recent work, Young (2009) revises the existent models of diffusion and makes a comprehensive

[2]The rule-of-thumb learning rules can be defined as follows: at each period, each agent constructs his posterior as a weighted average of his prior, his signal and the information he receives from neighbors.

comparison of the social learning model with the contagion model in marketing (Mahajan et al., 1990) and the social influence model in sociology (Granovetter, 1978).

In spite of the rich implications of social learning theory, the empirical identification of social learning effect is not easy. In his seminar work on social interaction, Manski (1993) uses the term of "reflection problem" to describe the difficulty of disentangling endogenous social effect (e.g. social learning) from exogenous social effect (contextual effect) in a *linear-in-means* model[3]. Subsequently by the discussions of Brock and Durlauf (2001) and Moffitt and Valente (2001), social learning effect is often confounded with common environment conditions or other group correlations that do not necessarily entail social learning. It raises even more concerns in the agricultural context because agricultural production generally depends on the common growing conditions.

To achieve convincing identification of social learning, one condition is to well define the reference group within which the learning process takes place. Then, different strategies can be employed to identify the social learning effect. Among others, Munshi (2004) compares the social learning effect on adoption of different HYV crops (wheat and rice) in the same district and finds that social learning is weak in a heterogeneous population. Bandiera and Rasul (2006) assume the effect of correlated unobservable is monotonic and test for non-linearities predicted by a model of strategic interactions in social learning. By doing so, they find an inverse–U shape social learning effect which depends on the number of adopters in the social network in Mozambique. Conley and Udry (2010) exploit the timing of news about neighbors productivity to test for social learning effect in the fertilizer use in Pineapple production in Ghana. They take special care in definition of reference group and control for environmental factors and find a positive social learning effect.

However, most of empirical studies investigate the effect of social learning on the adoption of new technology. Few has tested the social learning on the performance of new technology (except for the study of Conley and Udry (2010)). To the best of our knowledge, there is still no empirical evidence about social learning on the performance of sustainable agriculture in developing countries. To fill in this blank, we follow the literature of social network analysis and attempt to test the social learning effect on smallholder farmers' performance in the context of NRR in rural China. We will now turn to this special case and discuss the organization of social learning in the Sancha village.

4.3 The participatory social learning of organic farming

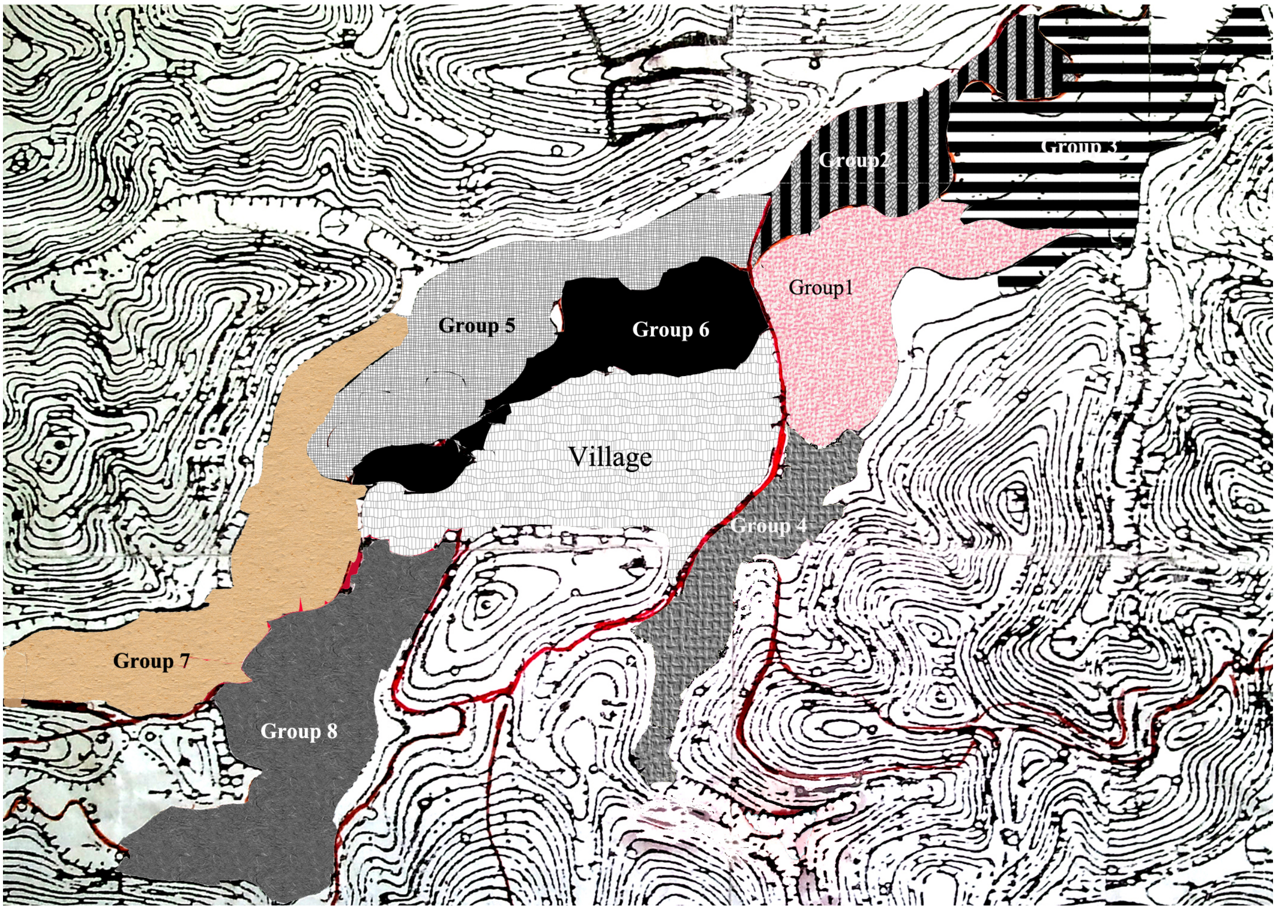
Sancha village was identified by a Hong Kong-based NGO, called Partnerships for Community Development (PCD), for a project of organic paddy rice production in 2005. At the beginning, the organic rice production was introduced to a small group of farmers in the form of field trials. The PCD, in collaboration with the Guangxi Maize Research Institute (GMRI), had assisted farmers' experiments of organic farming with technical guidance and marketing support. Through these field trials, a number of local knowledge such as pest control with local medicinal plants, composting and the "Duck-Rice" integrated system had been revived to adapt organic farming to local conditions.

In order to diffuse the successful experience of organic farming and get more farmers involved, the project opted for an approach of participatory social learning. According to the investigation of PCD, the rice production was organized on basis of four families (i.e. Li, Xu,

[3] In the linear-in-means model, the outcome of each agent depends linearly on his own characteristics, on its mean characteristics and on the mean outcome of his reference group.

Huang and Lu families) in Sancha village. The paddy fields were thus divided and exploited by four families labelled production group 1, 2, 3 and 4. Specifically, each family has 2 groups of paddy fields, one in the plain zone and another in the mountainous zone. As such, 8 groups of paddy fields were naturally defined. Map 3 provides an overview for the location of these groups. Nowadays under the Household Responsibility System (HRS), collective farming system has been broken into individual production, whereas the grouping of paddy fields remains unchanged.

Map 3. Groups of paddy fields in Sancha village



Source: Sancha village committee

The participatory social learning took place within these 8 groups for several reasons. Firstly, farmers worked simultaneously in the group as paddy rice production is a seasonal activity. They communicated during agricultural work to exchange information and ease the work. Also, their coordination was frequent in the group due to their collective management of water resource. Secondly, provided the small size of paddy field, farmers could directly observe the inputs and outputs of other farmers in the group, which favored the learning process. Thirdly, farmers spoke the same language in the group, which was essential for the social learning. With this understanding, workshops were organized within the group where all farmers of the group were united together to share their experience of organic farming. Farmers could then learn from their peers to improve their management of the technology or start their own experiment of organic farming. The learning is qualified as a social process as it not only takes place within the workshops, but also extends to farmers' interaction during their daily production. It is expected that in a process of social learning, farmers can generate their own knowledge and reduce the dependance on external assistance.

In this study, we follow the PCD definition of learning group for an investigation of social learning effect. Farmers' learning peers are defined as all farmers of the same group except for himself. We recognize the limitation of such a rough measure of social learning networks, for it cannot distinguish the specific links between agents (e.g. relatives and friends). However, the definition takes account of all potential learning sources and avoids measurement errors and omission of information in the learning process, which is appropriate in a smallholder environment. With this definition of reference group, the social learning effect could be captured by the peer effect of the group outcome on the individual outcome (i.e. agricultural performance defined as yield, technical efficiency or environmental efficiency). Still, the social learning effect can be confounded with other environmental factors. For instance, the inputs contamination or the agro–ecosystem could also collectively affect farmers' agricultural performance. Moreover, farmers' agricultural performance could depend on other social mechanisms such as altruism that do not necessarily entail social learning. In the next section, we will present our identification strategy to disentangle social learning from these confounding factors.

4.4 Identification of the social learning effect

As discussed in the literature review, estimating social learning effect raises three main challenges. Firstly, Manski (1993) divided social effects into an endogenous part (i.e. social learning effect) and an exogenous part (i.e., contextual influence). The separation of these two parts is a main challenge and thoroughly discussed as the *reflection problem*[4]. Secondly, the problem of "correlated effects" will raise when social learning needs to be identified from confounding environmental effects (i.e. factors related to common group environment). Thirdly, spurious correlation among members of the same reference group plague the identification if the formation of group is endogenous(Moffitt and Valente, 2001)[5]. These challenges call for appropriate statistical methodology which differs from one study to another. We will follow the literature to present our strategy addressing these challenges in our specific setting.

4.4.1 The basic model

Our model is an extension of the standard linear-in-means social interaction model in which we allow for plot–specific reference groups. Consider we have a set of plots i, $(i = 1, \dots n)$. Let $y_{i,t}$ be the agricultural outcome (e.g. yield) of plot i in season t. Let $X_{i,t}$ be a vector of plot owner's characteristics. Each plot i may have a reference group P_i of size n_i. This reference group is known by the modeller and contains all plots whose outcomes or owner characteristics may affect plot i's outcome. The collection of plot–specific reference groups thus defines an undirected network of plots[6].

Consider the following spatial autoregressive regression (SAR) model extended to social network economics (Brock and Durlauf, 2001) in which spatial units are plots and the peers effects are either contextual or endogenous. Formally, the structural model is formulated as:

[4] Manski (1993) has pointed out that the expected outcome from social equilibrium might be linearly depended on observed exogenous variables of a group in the model, i.e., the *reflection problem*.

[5] Here is the case where members in a group share common characteristics which leads to self–selection for the creation of the group.

[6] This corresponds to usual empirical formulation (e.g. Lee (2007)).

$$y_{i,t} = \alpha + \beta \frac{\sum_{j \in P_i} y_{j,t-1}}{n_i} + \theta y_{i,t-1} + \gamma X_{i,t} + \delta \frac{\sum_{j \in P_i} X_{j,t}}{n_i} + \tau_t + \varepsilon_{i,t}. \quad (4.1)$$

Note here we use the lagged peers' performance to avoid a potential simultaneity of outcome and β captures the endogenous social effect (i.e. social learning effect)[7]. δ captures the contextual effect and γ captures the effects of plot owner's characteristics (i.e. age, gender and education level). Given the underlying social process, the lagged errors $\varepsilon_{i,t-1}$ are correlated with the lagged peers' outcomes and if the errors are serially correlated, the estimation of β is biased since the $cov(\varepsilon_{i,t}, \frac{\sum_{j \in P_i} y_{j,t-1}}{n_i}) \neq 0$. The addition of lagged individual outcome $y_{i,t-1}$ thus helps to control for this potential bias. The τ_t is a dummy fixing five crop seasons in our data and the error term $\varepsilon_{i,t}$ reflects the usual i.i.d. disturbances with zero mean and an unknown variance associated with i.

To make it simpler, we can write the structural model in matrix notation.

$$y_{i,t} = \alpha\iota + \beta G y_{j,t-1} + \theta y_{i,t-1} + \gamma X_{i,t} + \delta G X_{j,t} + \tau_t + \varepsilon_{i,t}, \quad (4.2)$$

where y is an $n \times 1$ vector of outcomes, G is an $n \times n$ interaction matrix with $G_{ij} = 1/n_i$ if j and i are in the same reference group, and 0 otherwise, and ι is an $n \times 1$ vector of ones. G derives from our definition of reference group on basis of the village's social and geographical structure: (1) four families and (2) geographical location (either on plain or in mountain). Other socio-economic characteristics X which could influence the outcomes include the owner's age, gender and education level.

4.4.2 Identification strategy

The OLS estimation of equation 4.2 is naive since two types of spurious correlation within the reference group may exist in our setting. The first type of correlation is specific to the group environment. For instance, plots within the same group share the same water source. The agricultural outcomes of each plot i are thus interdependent due to inputs contamination (e.g. fertilizers). The second type of correlation is specific to individual characteristics. For instance, farmers of the same group may help each other which depends on individual unobservable characteristics. To purge these spurious correlation other than social learning, we employ a classical IV strategy and an alternative dependent variable strategy.

An IV strategy The first strategy relies on the random shocks of rats and pests attacks to the plots. In the context of smallholder farming, these ecological shocks cause significant damages to the rice production. As observed in Sancha village, the attacks of rats and pests are arbitrary in the time as well as in place. This observation leads to an assumption that the ecological shocks to a plot will influence its outcomes (i.e. yield and efficiency) but not that of its peers directly. On basis of this assumption, we can make use of peers' ecological shocks (i.e. average attacks of rats and pests to peers' plots) as instruments for peers' outcomes conditional on individual ecological shocks. The *exclusion restriction* of instruments will be checked by the Sargan over-identification test.

[7] Using the lagged performance of neighbors avoids the simultaneity problems since the current performance of the plot i cannot explain the past performance of his peers. However, some correlated variables explaining both the performance of the plot i in t and the group formation (and thus the performance of the group in $t-1$) may still present.

Equation 4.2 is thus firstly estimated using the IV estimator while controlling for group fixed effects ζ_G as follows:

$$y_{i,t} = \alpha\iota + \beta G y_{j,t-1} + \theta y_{i,t-1} + \gamma X_{i,t} + \delta G X_{j,t} + \zeta_G + \tau_t + \varepsilon_{i,t}, \tag{4.3}$$

Still, the concern about the farmers' altruism remains. Suppose farmers help each other to mitigate the damages of ecological shocks, this altruism could improve the outcome of the group as a whole. However, this collective improvement of outcome is not due to social learning and thus bias the estimation. This source of bias is related to the unobservable individual characteristics which could be controlled for in a Within model. Therefore, to deal with individual specific correlation and validate the IV estimation, equation 4.2 is estimated using the Within-2SLS estimator and controlling for plot fixed effect ν_i as follows:

$$y_{i,t} = \alpha\iota + \beta G y_{j,t-1} + \theta y_{i,t-1} + \gamma X_{i,t} + \delta G X_{j,t} + \nu_i + \tau_t + \varepsilon_{i,t}, \tag{4.4}$$

The first step regression is as follows:

$$G y_{j,t-1} = \rho_1 Grats_{j,t-1} + \rho_2 Gpests_{j,t-1} + \rho_3 \theta y_{i,t-1} + \rho_4 X_{i,t} + \rho_5 G X_{j,t} + \nu_i + \tau_t + \xi_{i,t}, \tag{4.5}$$

where ρ_1 and ρ_2 are the coefficients associated to the two instruments.

Alternative measure of outcome The second strategy relies on the use of technical efficiency (TE) and environmental efficiency (EE) as outcome measure. Here the TE represents farmer's managerial skill to maximize output at a given inputs level, whilst the EE represents his managerial skill to minimize environmentally detrimental input at a given output level. The use of efficiency term is of particular interest. Firstly, the managerial skill is more relevant and accurate for the social learning process. Secondly, the efficiency term is estimated from a production function. This process can purge correlations of outcomes due to contamination of productive inputs, e.g. fertilizers used in peers' plots. Thirdly, using two measures of efficiency, we can derive precise understanding about farmers willingness to learn with respect to economic performance and environment protection. In practice, the efficiency scores of TE and EE are estimated and discussed in details in Chapter 3. To save place, we do not develop the stochastic production frontier model here.

4.4.3 Technological heterogeneities

One important feature of smallholder farming is the technological heterogeneity. Specifically in our case, as farmers practice organic and conventional farming in the same group, the heterogeneity of technology could plague farmers' social learning and should be taken account in our analysis (Munshi, 2004). To this end, we divide our sample into two sub–samples according to production technology (i.e. organic farming and conventional farming) and identify the social learning effect within each sub-sample. The hypothesis is that social learning is more likely to happen with a homogenous technology than heterogenous technology.

This approach is useful to test the constraint of technological heterogeneity for social learning. However, it also raises a *self-selection* problem. Put another way, conditions for a farmer to practice organic farming may be different from his conventional counterpart. Farmers may thus *self-select* to the organic farming. The artificial division of sample will create biased estimation if the *self-selection* exists. To rule out this potential problem, we implement a Heckman correction to the estimation (Maddala, 1983).

To do so, we estimate the probability of farmer to practice organic farming as follows:

$$Organic_{i,t} = \gamma_0 + \gamma_1 Distance_{i,t} + \gamma_2 Pollution_{i,t} + \gamma_3 y_{i,t-1} + \gamma_4 X_{i,t} + \gamma_5 GX_{j,t} + \tau_t + \varepsilon_{i,t}, \quad (4.6)$$

where $Organic_{i,t}$ is a dummy variable indicating the organic status of the plot i at season t. The variables $Distance_{i,t}$ is the distance for the household to reach the plot from his house. $Pollution$ is a dummy variable coding 1 if the plot has at least one neighbor using chemicals fertilizer. We assume that these two variables are exogenous factors that determine farmer's choice for organic farming (more discussion about these instruments is found in Chapter 3). $y_{i,t-1}$ is the lagged performance of plot i. X is a matrix of plot owner's characteristics (i.e. age, gender and education level) and GX is a matrix of the same characteristics at group level. τ_t is a dummy fixing one of the five seasons. $\varepsilon_{i,t}$ is the error term.

From equation 4.6, we calculate the *Inverse Mills Ratio* (λ) and use it as a new control variable in the regression within each sub–sample, i.e., conventional and organic farming, as follows:

$$y_{i,t} = \alpha\iota + \beta G y_{j,t-1} + \theta y_{i,t-1} + \gamma X_{i,t} + \delta GX_{j,t} + \lambda_{i,t} + \tau_t + \varepsilon_{i,t}, \quad (4.7)$$

In equation 4.7, $y_{i,t}$ is the outcome of plot i in season t, i.e. the yield, the technical efficiency and the environmental efficiency. The equation 4.7 is then estimated by the OLS estimator, the 2SLS estimator and the Within-2SLS estimator.

4.5 Data and descriptive statistics

The dataset used in this study is the same dataset as we used in Chapter 3. Table 4.1 gives descriptive statistics of the main variables for this study and a summary of variable definitions can be found in Table 4.6 in Tables and figures.

Table 4.1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Rice yield(kg/mu)	342.12	94.59	43.75	750	1,007
Labor(person h/mu)	129.82	54.12	28.45	338.81	1,007
N(kg/mu)	14.13	3.97	4.98	34.5	1,007
Capital(Yuan/mu)	73.77	52.03	3.75	265	1,007
Water (1-3)	2.41	0.61	1	3	1,007
Technical efficiency (0-1)	0.73	0.12	0.33	0.98	1,007
Environmental efficiency (0-1)	0.45	0.19	0.08	0.96	1,007
Age	54.62	12.61	28	79	1,007
Sex (1 = female)	0.6	0.49	0	1	1,007
Education (0-12 years)	3.63	3.31	0	12	1,007
Organic (1 = organic)	0.34	0.47	0	1	1,007
Distance (categorical variable)	1.92	0.87	1	4	1,007
Pollution(1 = yes)	0.74	0.44	0	1	1,007
Rats (0-2)	0.49	0.57	0	2	1,007
Insects (0-2)	1.00	0.69	0	2	1,007

Source: authors' survey

From the descriptive statistics, we note that the rice production in Sancha village is principally implemented on small pieces of land (0.03 ha). It is conducted by senior (55 years) and female (60 percent) farmers, which is in line with the reality of labor outflow in the countryside. The large variation of inputs suggests that the production technology is heterogenous. For instance, about 34% of surveyed fields are under organic management, whilst 66% are under conventional farming. It is worth noting that most rice farmers have suffered ecological shocks, i.e. the attacks of pests and rats. More than half of farmers have reported to receive pests and rats attacks, so that the influence of ecological shocks should not be ignored in our analysis. Finally, we also note that the mean technical efficiency is higher (0.73) than the mean environmental efficiency (0.45) in the sample, which suggests that farmers have greater economic performance than environmental performance. In the following analysis, we will explore the dataset to investigate whether smallholder farmers could improve their performance in a social learning process and approve this participatory approach for sustainable agricultural development.

4.6 Econometric results

In this section, we present the identification results of social learning effect as discussed in previous section. A number of issues and policy implications raised by the results will be discussed.

First of all, we regress the individual rice yield on the group rice yield to test the social learning effect as benchmark. To deal with potential group correlated effects (e.g., environmental correlation) and individual correlated effects (e.g., altruism effect), we implement Within and Within-2SLS estimation in addition to the naive OLS estimation and make a step–by–step analysis (for completeness, see Table 4.7 in 4.6 for first stage IV regressions). As one can note in Table 4.2, after correcting for group and individual correlated effects (columns 3 and 4), we do detect a significantly negative correlation of yields within the reference group, which however disappears in the Within-2SLS estimation (columns 5).

The non-robust negative correlation is obviously not due to social learning, but rather due to contamination or spillover of inputs use (i.e. fertilizer and water). In fact, the competition of conventional and organic plots exists in the mixed total sample. It is plausible that the yield of organic plot could be negatively influenced by the overuse and leaching of chemical fertilizers from neighbor conventional plots. In turn, the yield of conventional plot is determined by chemical fertilizers which is constrained by neighbor organic plots due to conflicts and social pressure. The complex correlations of yields make it complicate to identify the social learning effect. To get rid of this concern, we now focus on the technical efficiency and environmental efficiency which are more relevant to social learning process.

Table 4.2: Social learning effect and rice yield in the total sample

	Dependent variable: agricultural yield				
	(1)	(2)	(3)	(4)	(5)
Lagged peers' yield	0.066	-.103	-.807***	-.411**	0.324
	(0.139)	(0.128)	(0.171)	(0.16)	(0.973)
Lagged individual yield		0.625***	0.592***	-.283***	-.298***
		(0.038)	(0.039)	(0.061)	(0.081)
Age	-.344	-.052	-.405	-405.360***	-62.362
	(0.548)	(0.414)	(0.505)	(128.174)	(451.420)
Sex	-17.126	-15.395	-18.599		
	(14.682)	(11.348)	(14.557)		
Education	1.324	0.037	1.231		
	(2.144)	(1.742)	(1.906)		
Rat					-13.410
					(16.271)
Pests					1.571
					(9.297)
Group age	7.606*	3.253	-3.664	416.210***	164.542
	(4.223)	(3.701)	(6.208)	(123.072)	(364.204)
Group sex	36.031	43.313	-64.025	-1634.042	116.241
	(66.600)	(64.571)	(242.264)	(2155.999)	(3115.265)
Group education	-11.587	-7.286	-1.157	-9.679	-9.498
	(7.048)	(5.803)	(7.925)	(12.768)	(12.262)
Intercept	229.770	101.094	1107.963**	1579.653	
	(271.292)	(231.007)	(527.650)	(1724.860)	
Control for Lagged yield		x	x	x	x
Group dummies			x	x	x
Individual fixed effect				x	x
Instrumentation					x
Observations	805	805	805	805	805
Number of plots	202	202	202	202	202
F statistic	6.526	38.1	38.201	24.86	13.275
R^2	0.073	0.453	0.477	0.223	0.196
RMSE	183.149	140.774	138.331	97.915	114.443
Hansen statistics					1.583
P-value Hansen statistics					0.208

Estimation method: OLS estimator in columns 1 to 3, within estimator in column 4 and within-2SLS in column 5. The dependent variable is the yield defined as the raw rice output per land area. Seasons dummies are controlled for in all regressions. Group fixed effects are controlled for in column 3 and plot fixed effects in columns 4 and 5. The variables sex and education are time invariant and thus dropped in columns 4 and 5. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.3 present the results when technical efficiency (columns 1 to 3) and environmental efficiency (columns 4 to 6) are used to measure plot's outcome. Columns 1 and 4 are estimated by simple OLS estimator. Columns 2 and 5 take care of environmental correlation by controlling for group dummies and applying the IV estimation. Columns 3 and 6 eliminate the altruism effect and give a causal effect of social learning by applying Within-2SLS estimation[8].

[8]The first stage regressions can be found in Table 4.7 in 4.6.

Table 4.3: Social learning effect and efficiency in the total sample

Dependent variable:	Technical efficiency			Environmental efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged peers' efficiency	0.003***	-.005	-.0005	0.006	0.114	1.072
	(0.0008)	(0.013)	(0.0004)	(0.023)	(2.142)	(1.006)
Lagged individual efficiency	0.978***	0.979***	0.994***	0.982***	0.975***	-.367***
	(0.0002)	(0.0009)	(0.002)	(0.006)	(0.082)	(0.063)
Age	-5.30e-07	-2.00e-06	-.0001***	-3.52e-06	0.00007	0.044
	(1.31e-06)	(1.55e-06)	(0.00004)	(0.0001)	(0.0008)	(0.03)
Sex	-7.08e-06	0.00003		0.004	0.005	
	(0.00003)	(0.0001)		(0.003)	(0.011)	
Education	9.50e-06*	1.78e-06		0.0003	0.0004	
	(5.11e-06)	(5.60e-06)		(0.0005)	(0.0005)	
Rats		-.0004**	-.00002***		0.001	0.01***
		(0.0002)	(6.15e-06)		(0.004)	(0.003)
Pests		-.00007	-7.95e-06**		-.006**	-.0002
		(0.00006)	(3.46e-06)		(0.003)	(0.002)
Group age	-.00002	-.00004***	9.68e-06	0.0002	0.001	-.052**
	(1.00e-05)	(1.00e-05)	(0.00003)	(0.0007)	(0.015)	(0.027)
Group sex	-.0007***	-.0007	0.0001	0.009	0.029	1.280**
	(0.0002)	(0.001)	(0.0006)	(0.01)	(0.157)	(0.558)
Group education	0.00005***	-1.00e-05	-2.79e-06	0.0005	0.001	0.001
	(1.00e-05)	(0.00002)	(5.72e-06)	(0.002)	(0.009)	(0.003)
Intercept	0.023***	0.03***		0.002	-.146	
	(0.0008)	(0.008)		(0.043)	(2.220)	
Group dummies		x			x	
Individual fixed effect			x			x
Instrumentation		x	x		x	x
Observations	805	805	805	805	805	805
Number of plots	202	202	202	202	202	202
F statistic	2,837,094	2,807,083	3,499,681	3,319.524	1,854.209	23.57
R^2	1	1	1	0.967	0.967	0.276
RMSE	0.0004	0.0005	0.00004	0.034	0.034	0.023
Hansen statistics		0.008	0.823		0.986	0.018
P-value Hansen statistics		0.928	0.364		0.321	0.893

Estimation method: OLS estimator in columns 1 and 4, 2LS estimator in columns 2 and 5, and within-2SLS in columns 3 and 6. The dependent variable is the estimated technical efficiency in columns 1-3, and the calculated environmental efficiency in columns 4-6. Seasons dummies are controlled for in all regressions, group fixed effects are controlled for in columns 2 and 5, and plot fixed effects in columns 3 and 6. The variables sex, education are time invariant and thus dropped in columns 3 and 6. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Note here in the case of technical efficiency, we detect a positive correlation among farmers when using a naive OLS estimator. However, the correlation becomes non-significant once confounding environmental factors and individual characteristics are controlled for. This result suggests the importance of group and individual correlated effects in our case, which need to be taken into account. Similarly in the case of environmental efficiency, the correlation is positive but non-significant. In contrast, the lagged individual performance is strongly significant, which suggests farmers' performance rely on their own experience, rather than others' performance. One plausible explanation to the absence of social learning effect is that in a heterogeneous population, it is difficult for farmers to learn from peers with different technology (Ellison and Fudenberg, 1993). The mixture of technology in total sample may thus plague the social learning process. To test this hypothesis, we divide the total sample into 2 sub–samples according to the production technology (i.e. organic or conventional farming). By doing so, we consider only peers who practice the same technology in the same group as learning reference.

Table 4.4: Social learning of conventional farming

Dependent variable:	Technical efficiency			Environmental efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged peers' efficiency	0.0007	0.011	-.0008	-.002	-.973	-.052
	(0.002)	(0.009)	(0.0006)	(0.087)	(0.63)	(0.264)
Lagged individual efficiency	0.978***	0.978***	0.993***	0.947***	0.925***	-.425***
	(0.0003)	(0.0005)	(0.001)	(0.012)	(0.018)	(0.078)
Age	4.11e-06**	5.07e-06**	-8.62e-05***	0.00009	-.00002	0.004
	(1.87e-06)	(2.08e-06)	(1.00e-05)	(0.0001)	(0.0002)	(0.008)
Sex	0.0002***	0.0002***		0.006*	0.005	
	(0.00004)	(0.00004)		(0.003)	(0.003)	
Education	7.24e-06	-1.03e-07		0.0008	0.001**	
	(6.01e-06)	(8.15e-06)		(0.0006)	(0.0007)	
Rats	-.00008*	-.00007	-2.24e-05***	0.003	0.002	0.004
	(0.00005)	(0.00005)	(8.23e-06)	(0.003)	(0.003)	(0.004)
Pests	0.00004	0.00003	-7.83e-06	-.011***	-.009***	-.004
	(0.00003)	(0.00004)	(5.15e-06)	(0.003)	(0.003)	(0.002)
Group age	0.00008***	0.00009***	-1.14e-06	0.002	0.00005	0.0008
	(0.00002)	(0.00002)	(6.36e-06)	(0.001)	(0.002)	(0.003)
Group sex	0.003***	0.003***	0.0002**	0.045***	0.008	0.014
	(0.0004)	(0.0005)	(0.00007)	(0.014)	(0.029)	(0.034)
Group education	0.0001***	7.53e-06	-3.35e-06	0.005*	0.016**	0.003
	(0.00003)	(0.0001)	(1.00e-05)	(0.003)	(0.008)	(0.004)
Inverse Mills ratio	0.00006	0.00003	-7.70e-06	0.0007	0.003	-.010
	(0.00007)	(0.00008)	(0.00002)	(0.006)	(0.006)	(0.017)
Intercept	0.016***	0.009		-.099	0.531	
	(0.002)	(0.007)		(0.08)	(0.431)	
Group dummies	x	x		x	x	
Individual fixed effect			x			x
Instrumentation		x	x		x	x
Observations	510	510	476	510	510	476
Number of plots	158	158	124	158	158	124
F statistic	2,452,183	2,290,952	2,170,216	1,345.496	1,062.598	16.176
R^2	1	1	1	0.971	0.969	0.328
RMSE	0.0004	0.0004	0.00004	0.033	0.033	0.021
Hansen statistics		0.699	0.975		0.536	0.227
P-value Hansen statistics		0.403	0.323		0.464	0.634

Estimation method: OLS estimator in columns 1 and 4, 2SLS in columns 2 and 5, and within-2SLS in columns 3 and 6. The dependent variable is the estimated technical efficiency in columns 1-3, and the calculated environmental efficiency in columns 4-6. Seasons dummies are controlled for in all regressions, group fixed effects in columns 2 and 5, and plot fixed effects in columns 3 and 6. The variables sex, education are time invariant and thus dropped in all regressions. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.4 reports results of the conventional farming sub–sample. The estimation results are regrouped by measure of outcome, i.e. technical efficiency in columns 1 to 3, and environmental efficiency in columns 4 to 6. For each measure, we run three regressions (OLS, 2SLS and Within-2SLS) as in previous analysis[9].

As indicated in Table 4.4, for farmers who practice conventional farming, their performances in terms of technical and environmental efficiency, depend essentially on their own experience rather than peers' performance. This is not surprising as conventional farming is practiced in the village since long time. Without effective organization and monitoring, small-

[9]For more completeness, Tables 4.8 and 4.9 in 4.6 gives the first stage regressions for Tables 4.4 and 4.5 respectively.

holder farmers have to handle the technology by themselves. Therefore, after a long period of self-experimentation, conventional farmers have achieved stable performance on basis of their particular conditions. Curiously, we note here female farmers have generally higher economic performance (i.e. technical efficiency) than male farmers at both individual and group level. This result suggests that organization of female group is an effective way to foster farmers economic performance. This finding is interesting and important for policy design in rural areas. We will compare this result with the results of organic sub–sample.

The same estimations (OLS, 2SLS and Within-2SLS) are applied to the organic sub–sample and table 4.5 reports the results. For the case of organic farming which is organized in the project framework, the results are more interesting. The effect of social learning is positive for technical efficiency. The magnitude is small(i.e., 0.0001-0.0007) but significant at 1%. The result suggests that for a new technology like organic farming, farmers learn from their peers as well as their own experience. The well organized participatory social learning is thus effective and efficient to foster smallholder farmers' economic performance of organic farming.

Nevertheless, the social learning effect is non-significant for environmental efficiency. Put differently, smallholder farmers are economic rational rather than environmental protectionist. They learn to maximize the yield but not to minimize the use of environmentally detrimental nitrogen, even in the case of organic farming. This result indicates the critical limitation of social learning process in promoting resource conservative agriculture. Without social learning, farmers will take long time to improve their environmental efficiency based on their own experience and external incentives. Therefore, government's guidance and assistance become necessary in the urgent situation of environment deterioration. In the case of Sancha village, more environmental education and extension service should be provided to support smallholder farmers.

To check the effect of female groups, we find that the role of female groups is even more important in the case of organic farming. Farmers in female groups have significantly higher performances in terms of both technical efficiency and environmental efficiency. This result is in line with our previous finding that women favor the adoption of organic farming in Sancha village (Chapter 2). This evidence has direct policy implication for the human development in rural China. In a time where women are becoming major labor force in agriculture (De Brauw et al., 2013), policy design should be more favorable with respect to the education and organization of women in rural areas. In any circumstance, women's interests, specificity and ability should be well recognized to promote a more performing and resource conserving agriculture.

Table 4.5: Social learning of organic farming

Dependent variable:	Technical efficiency			Environmental efficiency		
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged peers' efficiency	0.0006**	0.0007**	0.0001***	-.0002	0.053	-.051
	(0.0003)	(0.0004)	(0.00005)	(0.041)	(0.036)	(0.041)
Lagged individual efficiency	0.977***	0.977***	0.992***	0.981***	0.981***	-.403***
	(0.0003)	(0.0002)	(0.002)	(0.013)	(0.012)	(0.11)
Age	9.35e-09	-1.77e-08	-8.17e-05***	-.0001	-.0001	0.009**
	(1.54e-06)	(1.49e-06)	(1.00e-05)	(0.0002)	(0.0002)	(0.004)
Sex	-.0001**	-.0001**		0.0001	6.63e-07	
	(0.00004)	(0.00004)		(0.005)	(0.004)	
Education	-7.22e-06	-7.38e-06		0.0007	0.0005	
	(7.82e-06)	(7.61e-06)		(0.0008)	(0.0008)	
Rats	-.0004***	-.0004***	-.00002*	0.009*	0.008*	0.018**
	(0.00007)	(0.00007)	(9.66e-06)	(0.005)	(0.005)	(0.008)
Pests	-.00007	-.00007	-1e-05**	0.004	0.003	0.005**
	(0.00004)	(0.00004)	(4.60e-06)	(0.003)	(0.003)	(0.003)
Group age	-2.09e-06	-2.76e-06	2.67e-07	-.001	-.002**	-.001*
	(7.89e-06)	(8.02e-06)	(8.69e-07)	(0.0008)	(0.0008)	(0.0006)
Group sex	0.001***	0.001***	0.00009**	0.044***	0.045***	0.033**
	(0.0003)	(0.0002)	(0.00004)	(0.016)	(0.015)	(0.016)
Group education	-9.18e-06	-1.00e-05	-.00002**	0.012	0.01	0.003
	(0.00008)	(0.00008)	(8.11e-06)	(0.008)	(0.008)	(0.005)
Inverse Mills ratio	0.00008**	0.00008**	1.00e-05	0.008**	0.009**	0.011**
	(0.00004)	(0.00004)	(8.69e-06)	(0.004)	(0.004)	(0.004)
Intercept	0.023***	0.023***		0.01	0.0003	
	(0.0003)	(0.0003)		(0.024)	(0.028)	
Group dummies	x	x		x	x	
Individual fixed effect			x			x
Instrumentation		x	x		x	x
Observations	295	295	277	295	295	277
Number of plots	97	97	79	97	97	79
F statistic	2,349,133	2,335,665	1,111,516	743.114	742.532	7.243
R^2	1	1	1	0.966	0.966	0.341
RMSE	0.0003	0.0003	0.00004	0.036	0.035	0.022
Hansen statistics		0.007	0.174		0.118	1.342
P-value Hansen statistics		0.935	0.677		0.731	0.247

Estimation method: OLS estimator in columns 1 and 4, 2SLS in columns 2 and 5, and within-2SLS in columns 3 and 6. The dependent variable is the estimated technical efficiency in columns 1-3, and the calculated environmental efficiency in columns 4-6. Seasons dummies are controlled for in all regressions, group fixed effects in columns 2 and 5, and plot fixed effects in columns 3 and 6. The variables sex, education are time invariant and thus dropped in all regressions. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

4.7 Discussion and conclusion

As a prevalent form of agriculture, smallholder farming plays a crucial role in the sustainable agricultural development in developing countries. In order to empower smallholder farmers for ecological innovation such as organic farming, initiatives of participatory social learning are put forward and experienced within the framework of New Rural Reconstruction in China. The hypothesis is that smallholder farmers could learn from each other to revive local knowledge and improve their performance. If it is true, farmers could rely on themselves and reduce their dependance on external assistance for sustainable agricultural development.

This chapter aims to test this hypothesis with the experience in Sancha village from southwest China. We estimate the social learning effect on smallholder farmers' performances in a Spatial Autoregressive (SAR) model. To disentangle the social learning effect from environment related contamination effect and other individual related altruism effect, we make use of ecological shocks (i.e., rats and pests attacks) as instruments to run a IV-2SLS estimation and use technical efficiency and environmental efficiency as dependant variables. To investigate the technological constraints for social learning, we separate the sample by farmers' technology (i.e., conventional and organic farming) and compare the identification results.

In a step by step analysis, we demonstrate that social learning is conditional on the same technology. Precisely, farmers mainly depend on their own experience in the case of conventional farming. In the case of organic farming, the social learning effect is significant. Farmers learn from their peers as well as their own experience. This result suggests that for new technology such as organic farming, the organization of farmers for participatory social learning is an effective and efficient way to adapt the technology to local conditions and improve smallholder farmers' performance.

However, social learning is not an excuse to withdraw the agricultural extension service. We detect that smallholder farmers are economic rational rather than environment protectionist. Given their poor economic condition, smallholder farmers are more interested by the improvement of technical efficiency rather than the environmental efficiency. Without effective monitoring, the goal of environment protection will not be achieved through a social learning process, even in the case of organic farming.

By recognizing the limitation of social learning, our policy recommendation stresses the revival of agricultural extension system in rural areas. Provided the public finance constraints, the extension system has almost collapsed in China (Huang et al., 2004a; Jin et al., 2009). In absence of agricultural extension service, farmers are driven by economic interests and pursue the only objective of agricultural productivity. The serious consequence has been illustrated by increasing use of chemical inputs and environmental deterioration. Our study confirms once again the risk due to absence of effective agricultural extension service. Even using a environmental friendly technology such as organic farming, smallholder farmers' economic incentives will never change.

Finally, we recommend more attention to women in the sustainable agricultural development. As suggested by our study, female groups favor the smallholder performance, especially in the case of organic farming. This is probably related to women's advantage in communication, sensibility and availability, which is favorable for sustainable agriculture. Therefore, we should provide more opportunity and resource to educate and organize women in the design of sustainable agricultural program. We believe that the human and social capital in a feminized agriculture are the real assets for sustainable agricultural development in China.

Tables and figures

Definition of variables

Table 4.6: Definition of variables

Variable Name	Definition and description
Organic	Farmer's self report organic status. It's a binary variable coded "1" if the plot is under organic management, "0" otherwise.
Yield	The quantity of raw rice harvested from the plot at end of the season, the unit is "jin/mu".
Labor	Hours spent in paddy rice production on the plot. It is weighted by the age of farmer. The unit is "hours/mu".
N	The external Nitrogen input from organic source or inorganic source for the paddy rice production on the plot. The unit is "jin/mu".
Capital	Money spent for the rice production on the plot including the machinery, employment and seed cost. The unit is "yuan/mu".
Water	Index of water availability to the plot, range from 1 to 3. High index means good water availability.
Age	The age of the household head (in years).
Sex	The Sex of the household head: 1 = female.
Education	Years of education of the household head.
Distance	The geographical distance from farmer's house to the plot. Measured in minutes of walk. Range from 1 to 4.
Chemical pollution	The presence of pollution from chemical fertilizer application nearby the plot: With"1" yes and "0" no.
TE	Technical efficiency calculated from the SFA model.
EE	Environmental efficiency calculated using the method of Reinhard et al. (1999).
Rats	The damage caused by rats attacks. With "0" No damage, "1" I level damage and "2" II level damage.
Pests	The damage caused by pests attacks. With "0" No damage, "1" I level damage and "2" II level damage.

First stage IV regressions

Table 4.7: First stage IV regressions in the all sample

Dependent variable:	Lag peers' Yield	Lag peers' technical efficiency		Lag peers' environmental efficiency	
First stage reg. of	Col.5-Table 4.2	Col.2-Table 4.3	Col.3-Table 4.3	Col.5-Table 4.3	Col.6-Table 4.3
Lag group rats (t-1)	-33.963***	0.012	0.052*	-.003	0.003**
	(8.502)	(0.018)	(0.03)	(0.003)	(0.001)
Lag group pests (t-1)	6.618	0.0005	-.006	0.0004	0.003***
	(5.702)	(0.013)	(0.014)	(0.002)	(0.001)
Lag individual outcome	0.024**	0.056***	2.040***	-.038***	-.009
	(0.012)	(0.02)	(0.533)	(0.002)	(0.007)
Age	-393.896***	-.00004	-.017	-.0004***	0.014***
	(15.234)	(0.0001)	(0.013)	(0.00009)	(0.002)
Sex		0.01***		-.005**	
		(0.003)		(0.002)	
Education		0.0001		0.00003	
		(0.0005)		(0.0001)	
Rats	5.073*	-.011***	-.0002	0.001	-.0004
	(2.961)	(0.004)	(0.003)	(0.0009)	(0.0004)
Pests	3.028	-.004*	-.002	0.0008	-.001***
	(1.953)	(0.002)	(0.002)	(0.0007)	(0.0004)
Group age	344.269***	0.0005	0.005	-.007***	0.006***
	(13.796)	(0.001)	(0.012)	(0.002)	(0.002)
Group sex	-2550.105***	0.087*	-.867***	-.072	-.371***
	(267.119)	(0.048)	(0.288)	(0.051)	(0.03)
Group education	0.477	-.001	-.003	0.004**	0.0004
	(4.113)	(0.002)	(0.003)	(0.002)	(0.0008)
Intercept	4925.216***	0.61***	0.454	0.978***	-.450***
	(264.132)	(0.115)	(0.294)	(0.142)	(0.027)
Observations	805	805	805	805	805
Number of plots	202	202	202	202	202
F statistic	904.286	53.961	31.663	4272.102	6506.258
R^2	0.766	0.396	0.234	0.974	0.938
RMSE	25.096	0.038	0.024	0.011	0.004

Note: Robust standard errors. Seasons dummies are controlled for in all regressions, group fixed effects are controlled for in columns 2 and 4, and plot fixed effects are controlled for in columns 1, 3 and 5. The variables sex, education are time invariant and thus dropped in all regressions. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.8: First stage IV regressions and conventional farming

First stage regression of	Col.2-Table 4.4	Col.3-Table 4.4	Col.5-Table 4.4	Col.6-Table 4.4
Lag group rats	-.013**	0.011*	-.009	0.027**
	(0.006)	(0.006)	(0.01)	(0.01)
Lag group pests	-.006***	-.009***	-.009***	-.013***
	(0.002)	(0.002)	(0.002)	(0.002)
Lag individual outcome	-.033***	0.087	-.036***	-.082***
	(0.004)	(0.15)	(0.005)	(0.022)
Age	-.0001***	0.017***	-.0002***	0.032***
	(0.00004)	(0.002)	(0.00006)	(0.002)
Sex	-.001		-.003**	
	(0.0008)		(0.001)	
Education	0.0006***		0.0009***	
	(0.0002)		(0.0002)	
Rats	-.001	0.00006	-.002	-.00003
	(0.0009)	(0.001)	(0.001)	(0.002)
Pests	0.0009	-.001	0.001	-.002*
	(0.0007)	(0.0009)	(0.001)	(0.001)
Group age	-.001***	-.004***	-.004***	-.006***
	(0.0004)	(0.001)	(0.0007)	(0.001)
Group sex	-.030***	-.038***	-.040***	-.058***
	(0.005)	(0.012)	(0.008)	(0.019)
Group education	0.01***	0.001	0.014***	-.005
	(0.001)	(0.004)	(0.002)	(0.004)
Inverse Mills Ratio	0.002	-.004	0.004	-.008
	(0.002)	(0.004)	(0.002)	(0.006)
Intercept	0.874***	0.007	0.734***	-.920***
	(0.03)	(0.054)	(0.055)	(0.064)
Observations	510	510	510	510
Number of plots	158	158	158	158
F statistic	726.302	196.986	1042.97	295.084
R^2	0.967	0.741	0.968	0.831
RMSE	0.009	0.006	0.014	0.008

Note: The dependent variable is the lag of peers' technical efficiency in columns 1 and 2, and the lag of peers' environmental efficiency in columns 3 and 4. Robust standard errors. Seasons dummies and plot fixed effects are controlled for in all regressions. The variables sex, education are time invariant and thus dropped in columns 2 and 4. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.9: First stage IV regressions and organic farming

First stage regression of	Col.2-Table 4.5	Col.3-Table 4.5	Col.5-Table 4.5	Col.6-Table 4.5
Lag group rats	-.507***	-.532***	-.329***	-.358***
	(0.07)	(0.105)	(0.031)	(0.054)
Lag group pests	-.016**	-.021*	-.034***	-.049***
	(0.006)	(0.011)	(0.009)	(0.016)
Lag individual outcome	-.017	0.853	-.012	0.182*
	(0.018)	(0.614)	(0.013)	(0.1)
Age	-.00008	-.0008	-.00003	0.01***
	(0.0002)	(0.008)	(0.0002)	(0.004)
Sex	-.003		-.006	
	(0.004)		(0.005)	
Education	0.0004		0.0005	
	(0.001)		(0.001)	
Rats	0.01**	0.022**	0.008**	0.015
	(0.004)	(0.01)	(0.004)	(0.01)
Pests	0.001	-.0002	0.003	-.004
	(0.003)	(0.003)	(0.004)	(0.003)
Group age	0.002	0.001	0.001	0.0002
	(0.002)	(0.002)	(0.002)	(0.001)
Group sex	-.026*	-.054	-.038**	-.047
	(0.015)	(0.07)	(0.018)	(0.045)
Group education	0.011	0.011	-.002	0.002
	(0.016)	(0.011)	(0.022)	(0.008)
Inverse Mills Ratio	0.0005	0.012	0.004	0.018*
	(0.005)	(0.012)	(0.007)	(0.01)
Intercept	0.834***	0.298	0.642***	0.007
	(0.114)	(0.19)	(0.071)	(0.161)
Observations	295	295	295	295
Number of plots	97	97	97	97
F statistic	4611.076	120.862	647.641	68.41
R^2	0.936	0.803	0.881	0.689
RMSE	0.032	0.027	0.034	0.025

Note: The dependent variable is the lag of peers' technical efficiency in columns 1 and 2, and the lag of peers' environmental efficiency in columns 3 and 4. Robust standard errors. Seasons dummies and plot fixed effects are controlled for in all regressions. The variables sex, education are time invariant and thus dropped in columns 2 and 4. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

General conclusion

China is facing great population-environment conflicts in its economic development and transition. In order to feed its large population with its limited amount of agricultural land, an intensive agricultural strategy has been opted for during past decades and has led to serious environmental problems. In this context, a new wave movement of rural reconstruction (NRR) has emerged in the civil society. This movement provides alternative perspectives for sustainable agricultural development along with balanced objectives of food security and environmental protection. As a voice for critical reflection on agricultural modernization, the NRR stresses human development and adopts original social approaches to realize peasant-centered sustainable agricultural development. In order to understand its socio-economic foundation and derive policy implications for current agricultural and rural reform, this thesis draws on field work in a small Chinese village to provide in-depth case studies of the NRR movement. To the best of our knowledge, this is the first empirical economic evaluation of the NRR.

In the first case (Chapter 2), we demonstrate that social activities such as basketball matches are a cost effective means to create social networks among farmers with different cultural backgrounds. Within these social networks, farmers share information which is crucial for the successful diffusion of new technology. The identification of a large social network effect confirms that this social mechanism is efficient in the promotion of organic farming in this small village. Being regarded as a form of social capital, social networks are essential for the collective action of farmers, particularly in an atomized rural society. However, social network construction has been ignored since the implementation of the Household Responsibility System (HRS) in the 1980s. In order to revive farmers' cooperative spirit and empower them to participate in sustainable agricultural development, the government's rural infrastructure construction should be better combined with bottom-up social network construction as in the case of Sancha village.

In addition, our study identifies women, education and labor as important determinants of successful organic farming development. The policy implication is straightforward. Due to the development of the non-agricultural sector, young and male farmers prefer leaving agriculture to work in the city, resulting in the increasing feminization of agriculture[10]. In such a context, the role of women in agriculture becomes critical. Being more sensitive to health and environmental issues, women are important assets for sustainable agricultural development in rural China. Nevertheless, women generally have limited education in rural society. Therefore, agricultural extension services and environmental education programs should target women and take account of their specific needs, interests and expertise.

In the second case (Chapter 3), we question the sustainability of non-certified organic farming by comparing farmers' environmental efficiency within organic and conventional rice production systems. Using a Stochastic Frontier Analysis (SFA) approach, we test the hypothesis of the existence of a "technology gap" between organic and conventional farming. The re-

[10]The feminization phenomenon in Chinese agriculture is discussed more in detail in a recent paper by De Brauw et al. (2013).

sult suggests that the "technology gap" is non-significant in a smallholder environment where farmers can successfully substitute chemical fertilizers with organic fertilizers. In other words, smallholder farmers' conversion to organic farming does not jeopardize food security in China, as opposed to observations made in developed countries.

However, conversion to organic farming does not equal optimal management of resources such as nitrogen, which is environmentally detrimental in the Chinese context. Our analysis shows that without sufficient technical training and environmental education, farmers who are new to organic farming tend to overuse nitrogen and thus lose the advantage of organic farming. This phenomenon is particularly significant during the ramping up period of organic farming in the village, which would warn against excessive expansion of the project. However, rather than fault the project, we conclude that sustainable agriculture is not achieved by technology per se but depends on the performance of farmers who use the technology.

In the third case (Chapter 4), we continue to explore smallholder farmers' performance for sustainable agricultural development through the social learning process. Social learning is regarded as a participatory education approach adopted by many NRR projects. It is expected that farmers learn from each other and cultivate their performance through diffusion and sharing of local knowledge, thus minimizing their dependance on external aid. In our study, we find that the effect of social learning is non significant in the case of conventional farming. However, in the case of organized organic farming, social learning is found to be significant in fostering farmers' technical efficiency.

Nevertheless, the social learning effect is non-significant in terms of environmental efficiency. In other words, smallholder farmers are driven by economic motivations rather than environmental concerns. This leads to the conclusion that social learning is insufficient in promoting resource-conservative agriculture, so that more external intervention is needed. By recognizing the limitations of social learning, we also see the opportunity for a state-civil society partnership. In this regard, the government's agricultural extension services are necessary to compensate for the limitation of social learning and to guide smallholder farmers in the direction of resource-conservative agricultural development.

Today, as in the republican era, the rural reconstruction movement is growing as a response on the part of civil society to the overwhelming dominance of state politics. Since China's entry into the World Trade Organization, Chinese agriculture has been turning to the world market, which is dominated by developed countries. Agricultural industrialization seems to be the only choice to compete and survive in worldwide competition. Rapid urbanization and industrial development attract poor farmers to leave agriculture in an attempt to improve their livelihood. The exodus of rural labor is an increasingly predominant phenomenon. These factors drive the government's strategy of agricultural modernization. With an alternative ideology, the NRR's "anti-modernization" and peasant–centered approach are judged as conservative and unrealistic from the mainstream point of view. Without the government's political and financial support, most NRR projects struggle for growth and receive little attention.

What contribution should we expect from the NRR movement? From a scientific point of view, most NRR projects can be regarded as cutting-edge social experiments with engagement of civil society. These experiments are valuable in advancing our knowledge about human sustainability sciences. As demonstrated in this thesis, the experiment in Sancha village derives comprehensive understanding about the role of social activity-based networks in agricultural technology diffusion. It also detects and warns against the non-sustainable practices of organic farming by smallholder farmers. The benefits and limitations of the social learning process open further discussion about performance sources of smallholder farmers. The thorough understanding of smallholder rural society and organic farming provided by NRR projects are extremely important, because balancing large scale production and smallholder farming is a big challenge of sustainable agricultural development in China today.

From a political point of view, the NRR movement is fundamentally in line with the government's "New Socialist Countryside Construction" campaign. For instance, in 2006, the state's legislation passed a cooperative law to support the development of rural grassroots organizations. More recently, the central authority's 2013 No.1 document recognizes the predominance of family farms in agriculture and encourages their sustainable development. Within this political framework, the experience of the NRR could shape and influence government's agricultural policy design. For instance, more female–specific ecological programs and social organization could be integrated in the government's policy. Meanwhile, the bottom-up intervention of non-governmental institutions are indeed complementary to the application of current policy. For instance, the government's rural infrastructure construction could more closely correspond to local needs and support rural social construction. And the impact of NGO environmental education could be well reinforced by agricultural extension services in the promotion of environmentally friendly and resource conserving agriculture in rural areas.

As government and civil society share the same objective of sustainable agricultural development, a state-civil society partnership could be a promising solution to overcoming the limitations of the NRR and maximizing its benefits nationwide. With the government's increasing recognition of the role of civil society, intervention by more informal, non-governmental institutions and more decentralized approaches increasingly influence government decision-making and policy design. The development of sustainable agriculture is an art which needs not only top-down guidance but also bottom-up application.

From a global perspective, the Chinese NRR is not an isolated movement resisting agricultural industrialization. In the international peasant networks of *Via Campesina*, more rural movements led by peasants and civil society are happening around the world. The Chinese experiences of the NRR with respect to rural community construction, organic farming and farmer organization are thus informative references for similar initiatives that aim to promote peasantry for sustainable agriculture. To this end, more international exchange and regional cooperation are desirable to share valuable lessons and successful experiences. This will also open a perspective for future research on sustainable agriculture in developing countries.

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Appendices

Questionnaires

Questionnaire I : New Rural Reconstruction and Organic Farming	
Survey date	
Household ID	
Name	
Address	

I- Characteristics of household			
1	Age of household head		
2	Gender of household head		1=Female 0=Male
3	Education level of household head		0=Non 1=1st year of primary school 2=2nd year of primary school 3=3rd year of primary school 4=4th year of primary school 5=5th year of primary school 6=6th year of primary school 7=1st year of middle school 8=2nd year of middle school 9=3rd year of middle school 10=1st year of high school 11=2nd year of high school 12=3rd year of high school 13=college/university
4	Ethnic minorities		1=Yes 0=No
5	CCP member		1=Yes 0=No
6	Family belonging		1=Li Family 2=Xu Family 3=Huang Family 4=Lu Family
7	Housing condition	2008: 2009: 2010:	1=Mud house 2=Old brick house 3=New brick house
8	Number of family members	2008: 2009: 2010:	Reason of change:
9	Number of senior people older than 80 years	2008: 2009: 2010:	Reason of change:
10	Number of children younger than 5 years	2008: 2009: 2010:	Reason of change:

II- Economic conditions			
11	Area of paddy field	2008:	Reason of change:
		2009:	
		2010:	
12	Number of cattle	2008:	Reason of change:
		2009:	
		2010:	
13	Bio gaz	2008:	1=Yes 0=No
		2009:	
		2010:	
14	TV	2008:	1=Yes 0=No
		2009:	
		2010:	
15	Telephone or mobile phone	2008:	1=Yes 0=No
		2009:	
		2010:	
16	Tractor	2008:	1=Yes 0=No
		2009:	
		2010:	

III- Agricultural production and off-farm activity					
17	Plantation of sweet corn	2008:			1=Yes 0=No If yes, specify the area of plantation
		2009:			
		2010:			
18	Plantation of vegetable	2008:			1=Yes 0=No If yes, specify the area of plantation
		2009:			
		2010:			
19	Plantation of sugar cane	2008:			1=Yes 0=No If yes, specify the area of plantation
		2009:			
		2010:			
20	Plantation of peanut	2008:			1=Yes 0=No If yes, specify the area of plantation
		2009:			
		2010:			

21	Pig-breeding	2008:				1=Yes 0=No If yes, specify the numbers and the revenue of sales
		2009:				
		2010:				
22	Duck-breeding	2008:				1=Yes 0=No If yes, specify the numbers and the revenue of sales
		2009:				
		2010:				
23	Silk farming	2008:				1=Yes 0=No If yes, specify the numbers and the revenue of sales
		2009:				
		2010:				
24	Off-farm activity	2008:				1=Yes 0=No If yes, specify the revenue of activity
		2009:				
		2010:				
25	Remittance	2008:				1=Yes 0=No If yes, specify how much
		2009:				
		2010:				
IV- Organic and conventional rice production						
26	Definition of organic farming					
27	Motivation for organic farming					
28	Experience of organic farming	Since:				
29	Practice of organic rice production	2008:				1=Yes 0=No If yes, specify the area under organic management
		2009:				
		2010:				
30	Sales of organic rice	2008:				1=Yes 0=No If yes, specify the revenue of sales
		2009:				
		2010:				

31	Self-consumption of organic rice	2008:			1=Yes 0=No If yes, specify the value of self-consumption
		2009:			
		2010:			
32	Sales of conventional rice	2008:			1=Yes 0=No If yes, specify the revenue of sales
		2009:			
		2010:			
33	Self-consumption of conventional rice	2008:			1=Yes 0=No If yes, specify the value of self-consumption
		2009:			
		2010:			
V- New Rural Reconstruction and social network					
34	Participation in the Basketball matches (3times/month)	2008:			1=Yes 0=No
		2009:			
		2010:			
35	Distance from household to basketball court (walking time)				1=less than 5 mins 2=5-15 mins 3=more than 15 mins
36	Kinship relation with other household	Parents:			Specify the name
		Children:			
		Relatives:			

Questionnaire II : Organic rice production	
Survey date	
Household ID	
Field ID	
Name	
Address	

I- Field characteristics			
1	Location of field		1=Plain zone 0=Mountain zone
2	Distance from household to the field (walk time)		1=Less than 5 mins 2=5-15 mins 3=15-30 mins 4=More than 30 mins
3	Area of the field		
4	Quality of field		1=Grade I 2=Grade II 3= Grade III
5	Organic management	2008:	1=Yes 0=No
		2009:	
		2010:	
6	Presence of chemical pollution from neighbor fields	2008:	1=Yes 0=No
		2009:	
		2010:	
7	Presence of irrigation facility	2008:	1=Yes 0=No
		2009:	
		2010:	
8	Presence of pests lamp	2008:	1=Yes 0=No
		2009:	
		2010:	

FIRST SEASON			
II- Inputs of rice production			
A-Seed			
9	Species of seed	2008:	1=Hybrid 2=BX139 3=HG 4=HG 5=SYZ 6=GF2 7=FSYZ 8=GF6 9=BGX 10=GZA
		2009:	
		2010:	
B-Labor (hours person)			
10	Plowing	2008:	
		2009:	

		2010:	
11	Plantation	2008:	
		2009:	
		2010:	
12	Compost production	2008:	
		2009:	
		2010:	
13	Fertilization	2008:	
		2009:	
		2010:	
14	Weeding	2008:	
		2009:	
		2010:	
15	Pests control	2008:	
		2009:	
		2010:	
16	Harvest	2008:	
		2009:	
		2010:	
	C-Capital (Yuan)		
17	Plowing	2008:	
		2009:	
		2010:	
18	Irrigation	2008:	
		2009:	
		2010:	
19	Harvest	2008:	
		2009:	
		2010:	
20	Transport	2008:	
		2009:	
		2010:	
	D-Fertilizer (kg)		
21	Cow dung	2008:	
		2009:	
		2010:	
22	Pig manure	2008:	
		2009:	
		2010:	
23	Chicken manure	2008:	
		2009:	
		2010:	

24	Compost	2008:	
		2009:	
		2010:	
25	Compound fertilizer	2008:	
		2009:	
		2010:	
26	Urea fertilizer	2008:	
		2009:	
		2010:	
E-Pesticide (kg)			
27	Medicinal plants	2008:	
		2009:	
		2010:	
28	Chemical pesticide	2008:	
		2009:	
		2010:	
III- Output of rice production			
29	Raw rice yield (kg)	2008:	
		2009:	
		2010:	
IV- Other information			
30	Duck-rice system	2008:	1=Yes 0=No
		2009:	
		2010:	
31	Plantation of green manure	2008:	1=Yes 0=No
		2009:	
		2010:	
32	Pests attacks	2008:	0=No 1=level I 2=level II
		2009:	
		2010:	
33	Rats attacks	2008:	0=No 1=level I 2=level II
		2009:	
		2010:	
34	Draught	2008:	1=Yes 0=No
		2009:	
		2010:	
SECOND SEASON			
V- Inputs of rice production			
A-Seed			
35	Species of seed	2008:	1=Hybrid 2=BX139 3=HG 4=HG
		2009:	

		2010:	5=SYZ 6=GF2 7=FSYZ 8=GF6 9=BGX 10=GZA
	B-Labor (hours person)		
36	Plowing	2008:	
		2009:	
		2010:	
37	Plantation	2008:	
		2009:	
		2010:	
38	Compost production	2008:	
		2009:	
		2010:	
39	Fertilization	2008:	
		2009:	
		2010:	
40	Weeding	2008:	
		2009:	
		2010:	
41	Pests control	2008:	
		2009:	
		2010:	
42	Harvest	2008:	
		2009:	
		2010:	
	C-Capital (Yuan)		
43	Plowing	2008:	
		2009:	
		2010:	
44	Irrigation	2008:	
		2009:	
		2010:	
45	Harvest	2008:	
		2009:	
		2010:	
46	Transport	2008:	
		2009:	
		2010:	
	D-Fertilizer (kg)		
47	Cow dung	2008:	
		2009:	
		2010:	
48	Pig manure	2008:	

		2009:	
		2010:	
49	Chicken manure	2008:	
		2009:	
		2010:	
50	Compost	2008:	
		2009:	
		2010:	
51	Compound fertilizer	2008:	
		2009:	
		2010:	
52	Urea fertilizer	2008:	
		2009:	
		2010:	
	E-Pesticide (kg)		
53	Medicinal plants	2008:	
		2009:	
		2010:	
54	Chemical pesticide	2008:	
		2009:	
		2010:	
	VI- Output of rice production		
55	Raw rice yield (kg)	2008:	
		2009:	
		2010:	
	VII- Other information		
56	Duck-rice system	2008:	1=Yes 0=No
		2009:	
		2010:	
57	Plantation of green manure	2008:	1=Yes 0=No
		2009:	
		2010:	
58	Pests attacks	2008:	0=No 1=level I 2=level II
		2009:	
		2010:	
59	Rats attacks	2008:	0=No 1=level I 2=level II
		2009:	
		2010:	
60	Draught	2008:	1=Yes 0=No
		2009:	
		2010:	

Example of PCD's record

Household ID: 36
Season: 2007 2nd

Basic information:

Name : Bi Ailan (husband Xu Yongcheng)

Age : 42

Labor force: 2 adults (a daughter in primary school)

Cattle: No

Tractor: No

Main source of fertilizers: chicken manure, duck manure, compost

Main economic resource: husband work in construction

History of organic farming:

Experience: 6 seasons

Area: 0.45 mu

Location and environment: located in the pilot zone (plain zone), with no chemical pollution around. Irrigation facility is present near the field.

Last yield: 225kg GNZ

Record of production:

Seed species: BGX (0.4 mu) and 781 (0.8 mu)

Duck-rice system : raised 14 ducks for 2 years

Fertilization: 50kg commercialized organic fertilizer and 30kg compost and animal manure

Pesticide: use organic pesticide for 2 times

Yield: 150kg BGX and 350kg 781

Sales of organic rice: 50kg GNZ and 50kg BGX (price: 7yuan/kg)

Motivation for organic farming: Bi was suffering from headache for long time. She now believes that the chemical fertilizers are bad for the health, whilst organic rice is good taste and good for the health.

Remarks: Bi Ailan worked in the city for years. She returns back to the countryside and practices organic farming in all of her paddy fields.

Date: October 12, 2007

Contents

List of Tables

THE "NEW RURAL RECONSTRUCTION" MOVEMENT AND SUSTAINABLE AGRICULTURAL DEVELOPMENT IN CHINA

Cette thèse étudie le mouvement de la Nouvelle Reconstruction Rurale (NRR) sous l'angle du développement durable, en prenant l'exemple concret du village de Sancha, une communauté rurale de la province du Guangxi en Chine. Initié en 2003, la NRR est un réseau national de projets de développement qui réunit des intellectuels, des étudiants et des organisations dont l'objectif est d'expérimenter différents modèles de développement agricole et rural en Chine. Comme alternative à l'industrialisation agricole, la NRR favorise la coopération entre les petits agriculteurs, le savoir-faire local et l'agro-écologie pour le développement durable de l'agriculture. Afin de comprendre ses caractéristiques institutionnelles, son fonctionnement et son impact, nous avons mené une enquête dans le village de Sancha pour collecter des données sur les comportements socio-économiques de petits exploitants agricoles, et proposé trois études de cas sur la NRR.

Nos analyses empiriques suggèrent que la NRR a promu le développement de l'agriculture biologique dans le village. Les activités sociales sont efficaces pour la construction du réseau social via lequel l'agriculture biologique a été diffusée rapidement. Néanmoins, sans la formation technique suffisante et continue, les paysans récemment convertis à l'agriculture biologique tendent à surutiliser l'azote et perdent leur avantage environnemental dans la riziculture. Pour améliorer la performance des petits paysans, l'apprentissage participatif social paraît utile mais limité car les petits agriculteurs sont plutôt tirés par la performance économique que par la protection environnementale. De ces résultats, nous recommandons un partenariat Etat-société civile qui combine les services d'extension agricole du gouvernement et la reconstruction rurale ascendante pour l'objectif commun d'une agriculture durable en Chine.

Mots-clés : Nouvelle reconstruction rurale, Agriculture durable, Agriculture biologique, Chine.

This doctoral thesis studies the New Rural Reconstruction (NRR) movement from a sustainable development perspective, through a concrete case of Sancha village, a rural community in China's Guangxi province. Initiated in 2003, the NRR is a grassroots network of development projects which unites intellectuals, students and organizations to experiment with different models of agricultural and rural development in China. As an alternative to agricultural industrialization, the NRR favors the cooperation of smallholder farmers, local knowledge and agro-ecology for sustainable agricultural development. In order to understand the NRR's institutional characteristics, functioning and impact, we conducted a survey in Sancha village to collect data on smallholder farmers' socio-economic behavior and performed three in-depth NRR case studies.

Our empirical analysis suggests that the NRR has promoted the development of organic farming in the village. Social activities are cost-effective for social network building where organic farming is diffused rapidly. Nevertheless, without sufficient, ongoing technical training, farmers newly converted to organic farming tend to overuse nitrogen and lose their environmental advantage in rice production. To improve the performance of smallholder farmers, participatory social learning appears useful but limited because smallholder farmers are interested in economic performance rather than environmental protection. On basis of these results, we recommend a state-civil society partnership which combines the government's agricultural extension services and bottom-up rural reconstruction for the common objective of sustainable agriculture in China.

Keywords: New rural reconstruction, Sustainable agriculture, Organic farming, China.