The Pennsylvania State University

The Graduate School

College of Agricultural Sciences

LABOR MOBILITY, INTRAHOUSEHOLD DECISION-MAKING, AND AGRICULTURAL LAND LEASING: AN EMPIRICAL STUDY WITH AGENT-BASED MODELING IN RURAL SOUTH CHINA

A Dissertation in

Agricultural, Environmental and Regional Economics and Operations Research

by

Lin Zhang

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

August 2011

The dissertation of Lin Zhang was reviewed and approved* by the following:

Jill L. Findeis
Distinguished Professor of Agricultural, Environmental and Regional Economics and Demography
Dissertation Advisor
Chair of Committee

David Abler
Professor of Agricultural, Environmental and Regional Economics and Demography

Leif Jensen
Professor of Rural Sociology and Demography

Rhonda BeLue
Assistant Professor of Health Policy and Administration

Ann Tickamyer
Professor of Rural Sociology
Head of the Department of Agricultural Economics and Rural Sociology

*Signatures on file in the Graduate School.

ABSTRACT

Motivated by the coexisting challenges and opportunities facing rural farm households in rural south China, this dissertation investigates three particular issues concerning both intrahousehold and interhousehold interactions under the profound impact of labor rural-urban migration. Specifically, the first objective is to gain a better understanding of intrahousehold welfare distribution and the intrahousehold sharing rule through labor time allocation. The second objective is to understand the underlying individual rural farm household's decision-making structure under the impact of rural-to-urban migration. The third objective is to explore the dynamics surrounding household decision-making, related to the formation of land and labor markets. For the third objective, potential scenarios are simulated using agent-based modeling to address the impacts of growing off-farm work opportunities, new agricultural technology adoption and diffusion, and land policy reform at the village level.

This dissertation uses a baseline socioeconomic face-to-face household survey and key informant interviews undertaken for a project funded by the McKnight Foundation on phosphorous-efficient soybean cultivars being developed and now being released in south China; the survey and KI interviews were conducted in rural south China in summer, 2006. The survey was designed to provide an initial understanding of crop production (including soybean production decisions and anticipated P-efficient soybean adoption decisions), food consumption preferences, labor time allocation, land holding behaviors, and soybean and soybean product markets in the south China region. The KI interviews were designed to understand local trends in agriculture, soybeans, and the strong trend toward labor out-migration observed in the south China region.

Labor migration issues have been of great interest in development economics. Past studies of labor migration in China have largely focused on rural migrants to urban areas, while little attention is typically given to those who remain behind in the villages. More young adult and mid-age laborers flowing to exurban and urban regions for higher-wage off-farm employment may leave women, the elderly and very young household members behind, with more farm land available for cultivation in the village. Those left behind in the villages in China are responsible for agricultural production to secure the food supply for the most populated country in the world; and many are, at the same time, seeking jobs in nearby rural labor markets with the hope of bringing in extra income to improve their living conditions. Since off-farm work opportunities in urban, exurban and rural areas provide alternative sources of income to farm households, this is likely to affect intrahousehold resource allocation, labor time allocation, and farm production decisions of those who stay behind. Further, the entire household decision-making structure also may be affected such that the younger 'next generation' – having migrated for off-farm jobs –is no longer involved in making decisions influencing the farm and ultimately influencing food production for China.

In this dissertation, a collective modeling framework is used to analyze rural farm household labor supply behaviors in south China. Labor time allocation is modeled, while the imperfect wage labor market imposes constraints on off-farm labor supply and requires proper measurement of the farm shadow wage. The marginal product of labor (MPL) of on-farm production is estimated based on Jacoby's shadow wage method, which is essential to provide appropriate estimation of labor supply functions. Using labor time allocation as an assignable good, the intrahousehold nonlabor income sharing rule is derived. Furthermore, the impacts of the intrahousehold sharing rule, work participation behaviors, and other household characteristics are examined to analyze intrahousehold decision-making structure.

The results show that husband's labor supply is affected by his own and his wife's wage. Nonlabor income also has a significant effect on his labor supply. Wife's labor supply behavior does not change with changes in own wage or nonlabor income. Being less responsive in labor supply, wives are found to be more altruistic than husbands in transferring nonlabor (pooled) income to the spouse, when wage income increases. Labor income, nonlabor income, and local out-migrant sex ratio by county and by age category all show significant impacts on the intrahousehold sharing rule.

The estimation results also suggest that an increase in her share of nonlabor income yields a greater likelihood of the wife being engaged in marketing and in multiple production and innovation decisions, but no effect was found for most day-to-day farm production or household consumption decisions. This provides empirical support that transferring nonlabor income from husband to wife will likely increase her engagement in household decision-making but the effect is likely limited to certain decision-making categories. A higher wife's off-farm wage increases her involvement in making joint decisions for the household with her husband, relative to her husband making these decisions alone. Husband's home production participation predicts a more balanced husband-wife joint decision-making structure, relative to a more traditional husband-dominant decision-making structure. Husband's off-farm employment influences on-farm production decision-making, and especially increases wife's chance of making decisions alone or making joint decisions with her husband. Household males making joint decisions on soybean cultivar adoption is *negatively* affected by the off-farm work distance of the husband, but *positively* affected by the work distance of the wife. The likelihood of the wife making decisions alone is not found to be influenced by the distance that her husband needs to travel to his off-farm job. However, remittances are found to positively effect on males within the household making joint decisions as a group, and a greater schooling gap between husband and wife means that she is less likely to make decisions on her own relative to her husband making the household's decisions alone.

Finally, agent-based modeling simulations are incorporated with a classical game-theoretic approach. The simulation results demonstrate that, *first,* under the assumption of perfect labor and land markets, the initial ratio for agents' participation in a land-leasing strategy determines the development speed of the land-leasing market. The higher the initial ratio of land-leasing (to labor-hiring) agents, the less time required for land-leasing market formation. This implies that, with other factors kept constant, policies to relax land rental restrictions will strongly encourage farm households to participate in the land-leasing market and speed up the land-leasing market formation process. *Second,* imperfect off-farm labor markets in surrounding areas cast negative effects on land-leasing market development within the villages. The greater the difference between farm and nonfarm payoffs, the lower the incentives for farmers to invest in farm production. The land-leasing market formation process is delayed as a result. From a policy point of view, in addition to the considerable efforts of removing farm land rental barriers needed at the village level, another focus for policy-making should be to further develop labor markets in surrounding areas and reduce transaction costs associated with off-farm employment. *Third,* when land value increases as a result of new agricultural technology adoption and diffusion, households can be expected to switch to a land-leasing strategy despite land policies restrictive to land-leasing. However, an isolated approach of new technology adoption and diffusion (only) provides limited impacts on land-leasing market development, with other policies still needed to further speed up the process. *Finally,* land policies that focus on offering proper protection in land-leasing transactions will encourage farm households participating in the land-leasing market. With proper land-leasing policies in place to secure land use rights and transactions, the land market emerges rapidly even without significantly increasing the land value. Such policies will also lead to robust growth of the land-leasing market despite labor market imperfection effects.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I am grateful to many people for their encouragement, assistance, and faith in me throughout the years I pursued my Ph.D. degree. I would like to express my deepest appreciation to my adviser, Dr. Jill Findeis, whose invaluable assistance and comments helped me to successfully complete my dissertation. I greatly appreciate her insight in conducting research and her encouragement that allowed me to think independently and to find my own strengths and weaknesses to become a better researcher. I also deeply appreciate other committee members, Dr. David Abler, Dr. Leif Jensen, and Dr. Rhonda BeLue, who provided valuable suggestions and insights into this research.

I am grateful for the financial support I received from the McKnight Foundation for five years of Ph.D. course work study and a trip to south China for data collection. My research trip to south China would not have been successful without the assistance and support from the Root Biology Center at South China Agricultural University (SCAU) and Guangxi Agricultural Academy. I enjoyed working with the faculty and graduate students at SCAU and researchers at Guangxi Agricultural Academy. Particularly I would like to give my deepest gratitude to Professor Xiaolong Yan. His passion for China's agricultural development and Chinese farmers will inspire me in my current and future research. I will forever remember him as a mentor and a friend.

I am also grateful for the Department of Agricultural Economics and Rural Sociology at Penn State University and Department of Economics at Susquehanna University. My appreciation particularly goes to Dr. Jill Findeis, Dr. Stephen Smith, Dr. Ann Tickamyer, Dr. Edward Jaenicke, Dr. James Shortle, Dr. Stephan Goetz, and Dr. Ali Zadeh for their full support of my teaching at both universities.

My friends at Penn State University and outside the university give me so much charitable memories in all those years in the U.S. To Yan Zhuang and Xiao Meng for sharing their experience as proud first-time moms during our busy graduate lives. To Xiao Meng's husband Haiqing Xu for helping out with econometrics questions. To Yanguo Wang and Zhen Wu for practicing driving with me and being there for my failure and final success of obtaining my drivers license. To Kelly Ward for accommodating my husband and me when we just arrived in this country, and not to forget introducing gun-and-bow shooting experience to us. To Jiayi Li for having ice cream together and all the fun topics we talked. To my neighbors David and Joyce Stoner, and Pam Dick for their friendship and caring for me and my family.

I would like to thank my family for their support and love for each day of my life. To my father, Xiangcai Zhang, for trusting me in my abilities and being the best caring dad of the world — never failing to provide me with help and support whenever I needed, even if it means flying half of the earth twice a year. To my sister, Ying Zhang, for encouraging me study abroad and taking care of dad for those years that I was not around. To my son, Maximus, for all your sweet hugs, kisses and being my everyday sunshine. To my unborn daughter for my happiness received from your every little kick. Last but not least, to my husband, Francois Weeseman, for sharing my tears and laughs from the day we met, and for bounding our lives together and filling my heart with love and joy.

DEDICATION

To my mother, for forever loving me and never leaving me…

Chapter 1

INTRODUCTION

1.1. Introduction and Motivation

The Green Revolution has been argued as a great success for improving food production globally (Hayami and Otsuka, 1994; Estudillo and Otsuka, 1999). However, the impact is less significant in regions that are poor in soil nutrition and water availability (Evenson and Gollin, 2003; Otsuka and Kalirajan, 2006). Besides concerns of negative impacts of agricultural production on the environment (such as nutrition spill in groundwater contamination) (Rosegrant and Pingali, 1994; Tilman, 1998), the diffusion of new agricultural technology often encounters real-world economic bottlenecks such as credit constraints among farm households (Feder, 1982; Feder and Umali 1993; Findeis et al., 2005), farm size and land tenure status (Just and Zilberman, 1983; Soule et al., 2000) and lack of access to extension services (Birkhaeuser et al., 1991; Evenson, 2001). As a result of these and other constraints, Lynch (2007) concluded that in vulnerable environments, even if the new agricultural technology is readily available, traditional crops and crop varieties are often grown rather than the improved cultivars that could be much more productive.

As the world's most populated county, China constantly faces the simultaneous challenges of population growth and resource limitations (Brown, 1995; Fischer, 2001; Shi, 2002). It is socially desirable that economic development through technology progress accommodates the ever-rising demand for social wellbeing without imposing more pressure on the environment and natural resources (Harris and Kennedy, 1999; Breman et al., 2001). New technology advancement is important for the agricultural industry to secure the food supply under conditions of limited arable land, water and other natural resources (e.g., phosphorous and other essential minerals and nutrients) (Lynch, 1997; Fuglie and Kascak, 2001; Doss, 2006).

This dissertation is part of a multidisciplinary project funded by the McKnight Foundation to improve food security while enhancing soil quality in vulnerable tropical environments. The Lynch Lab in the Horticulture Department at Penn State University and the Root Biology Center at South China Agricultural University (SCAU) have jointly developed new soybean cultivars with superior root architectures; soybean cultivars were bred to grow in the low-phosphorous tropical soil conditions found in south China and are capable of better utilization of soil nutrition and water. Average yields of the new soybean cultivars are 20 to 30 percent higher than traditional soybean cultivars now grown in south China (Yan et al., 2004). Adoption of new P-efficient soybean cultivars is expected to 1) increase soil productivity over the long term with less chemicals and fertilizers; 2) improve income and human nutrition among men, women and children; and 3) be economically beneficial for bio-energy production and animal feed, especially for China, the world largest soybean importing country[1].

Yet the potential success of the new technology relies not only on the characteristics of the technology itself and associated markets, but also on other socioeconomic conditions of the local village context and of households themselves that have the potential to affect adoption and diffusion processes. For the south China case, rural-to-urban migration trends are dominant, with a booming economy in nearby urban and exurban regions strongly attracting labor away from the rural countryside and farming (Weinstein, 1996; Au and Henderson, 2006). Nonfarm (off-farm) income well exceeds farm income for those engaging in the nonfarm employment sectors (Zhao, 1999; Zhu, 2002). Labor migration and nonfarm (off-farm) employment can be expected to alter

[1] Food and Agriculture Organization of the United Nations (FAO) data show that China is the world's leading soybean importing country from 2000 to 2008 http://faostat.fao.org/site/342/default.aspx.

farmers' farm production behaviors and even farm household structure itself, and thus influence intrahousehold resource allocation, welfare distribution, and incentives for adoption of new agricultural technologies. For those staying on the farm, agricultural production may continue as their primary income source and major source of nutrition. For the rural elderly (those typically remaining on the farm), the new P-efficient technology may be particularly important. Further, the majority of rural labor migrating to urban regions can be expected to eventually return to the villages, mainly due to administrative controls on population flows, such as the Hukou system (see section 2.4.1). For the majority of the rural population returning to rural regions (e.g., due to job loss), agricultural production may well serve as a safety net (Kung, 2002). Therefore, analysis of new technology adoption cannot be isolated from labor out-migration impacts on farm production behaviors. Finally, measures of intrahousehold resource allocation are critical to understand farm household decision-making, and ultimately impacts in the process of rural economic development and, importantly, new technology adoption and diffusion.

For China, but also elsewhere, knowledge of rural-to-urban labor migration decisions is crucial for a wide variety of policy issues, including 1) reducing poverty and rebalancing income distribution between urban and rural regions (de Janvry and Sadoulet, 2001; Park, 2004; Du et al., 2005; Hertel and Zhai 2006; Winters et al., 2010), 2) social stability and potential effects on urban employment (Todaro, 1969, 1976; Gupta, 1987; Zhai and Wang 2002; Zhang and Song, 2003), and 3) food security and loss of the rural labor force from agricultural production (Carter 1997; Ruben and Van den berg 2001; Kilic et al., 2009). According to census data from the National Bureau of Statistics of China, the rural population in China decreased from 82 percent of the total population of China to 56 percent between 1978 and 2006, as total population increased from 962.6 million to 1.3 billion. At the end of 2006, among the 531 million rural labor force[2], 132 million were migrant laborers[3] working in off-farm jobs. Zhang and Song (2003) suggest that the major driving force for internal migration in China is the fast-growing economy and massive-scale urbanization, which forms geographic differences in economic opportunities (Li and Li, 1995; Wei, 1997; Hu, 2002; Fan, 2005).

The large-scale Chinese labor migration issue was brought to public attention by China's 1990 census (Davin, 1996). Later literature focused attention on the issue of Chinese out-migration from rural areas for urban employment opportunities, creating an extremely large new floating population of rural-urban migrants (Seeborg et al., 2000; Liang and Ma, 2004) and intra-province migrants (Zhang and Song, 2003). Extensive research has shown that the majority of the migrating population is engaged in off-farm employment simultaneously with part-time farming, rather than in permanent migration (Yang, 1997) or as short-term laborers rather than long-term settlers (Ping and Pieke, 2003; Li 2006; Chen and Hoy, 2008; Zheng et al., 2009; Gravemeyer et al., 2010). Rural labor out-migration tends to divert national investment resources towards the larger towns and cities, which may jeopardize rural development (Taylor, 1996). But remittances sent home by migrants help to improve the distribution of income between rural and urban populations (Stark and Lucas, 1988; Taylor, 1999; Hoddinott, 2003). Out-migration also can lead to easier accessibility to market information and new technology for agricultural production (Gould, 1994), as the rising demand for rural output from the cities can be expected to stimulate agriculture and rural industrialization, thus helping to raise incomes of rural households (Zhao, 2002).

---

[2] Rural labor force refers to the resident population living in the rural household for more than 6 months. Individuals are at least 16 years old and possess work abilities.

[3] Due to the Chinese government administrative control (i.e., Hukou policy), rural migrant laborers are less likely to permanently migrate to urban regions. Instead, migrant workers form a floating population that drifts between rural and urban regions.

The dramatic shifts of labor from rural to exurban-urban locations in China are expected to exert impacts on farm production and consumption, including farm labor demand and supply, willingness to adopt new agricultural technologies, and changes in farm land use. The substantial labor shifts in rural China due to out-migration reduces the underemployment problem in the agricultural sector, but at the same time, a significant proportion of its working-age population is at least temporarily lost to nonfarm employment (Seeborg et al., 2000); this may depress yields and discourage investment in high-productivity agricultural technologies (Rozelle et al., 1999). The high level of participation in non-agricultural labor markets is expected to eventually result in development of land rental markets in China (Deininger and Jin, 2005), but out-migration may reduce the incentive for land conservation activities and discourage farmers from adopting agricultural innovations (Niroula and Thapa, 2005). However, a reduction in the labor-land ratio may stimulate the need for less labor-intensive agricultural production techniques (Burke, 1979; Feder et al., 1985).

Past studies of labor migration in China have largely focused on rural immigrants in urban areas, with little attention given to those remaining behind in the villages. The adoption and diffusion of any new agricultural technology, including the new phosphorous-efficient soybeans, can be expected to be influenced by the very substantial migration trends now observed in south China. *It is important to emphasize that the rural population remaining at the origin in China is responsible for agricultural production to secure the food supply for the most populated country in the world.*

1.2. Project Background

The socioeconomic analysis, a coordinated effort between economists at Penn State University and at South China Agricultural University (Findeis, Cui, Zhang), aims to understand adoption and diffusion at study sites in Guangxi, Hunan, and Guangdong Provinces in south China, in collaboration with biologists from Penn State University and south China Agricultural University (Lynch, Yan, Nian, Hong, and graduate students). The sites were selected to provide baseline *ex ante* data for future assessment of long-term impacts. The project targeted regions with limited soil nutrient and water availability. In villages in south China, growing legumes is part of the traditional local agricultural production system, but with P-deficient tropical soils and arable land largely located at the mountain side (especially in Guangxi and Guangdong Provinces), soil texture is unsuitable to preserve and utilize add-in nutrition[4](Yan, 2004). The acute issue of low legume productivity due to low soil fertility can be reduced through breeding new cultivars with P-efficient root architectures. Cultivars with superior root structure are better at utilizing limited nutrients in the soil and obtaining water needed for plant growth and root tissue maintenance (Lynch, 2007). The ability to identify root trait characteristics and functions allows biologists to modify and develop new crop cultivars suitable for poor soil and climate conditions, and can improve utilization of scarce soil resources with less impact on the environment. The legume root architecture approach is also of growing importance worldwide, given increasing fuel costs and concerns regarding climate change (Lynch, 2007).

Assessment of adoption behaviors will occur following introduction of the soybean cultivars, as part of the *ex post* assessment of technology adoption and diffusion processes. The purpose of this dissertation is 1) to provide an understanding of intrahousehold dynamics that may affect who makes decisions, under conditions of strong out-migration, and 2) simulated responses of land and labor markets in the longer term, as households adjust to strong out-migration trends coupled with yield increases. Decision-making has become an important

[4] Other study sites are mainly located in Mozambique, where similar soil conditions are identified with a more urgent demand for food consumption and poverty alleviation than in the South China study sites.

research topic in economics and the *ex ante* data allow analysis of factors influencing engagement in decision-making (farm production, consumption, etc.) when households are increasingly mobile and spread out over space. This is, in many respects, a question of household governance and what being a 'household' means under conditions of spatial mobility. One important decision, from the perspective of this research, is whether or not new cultivars are adopted and diffused. Whether the next generation is engaged in making this decision – as opposed to elderly parents (alone) – may influence the outcome. It is well established that adoption decisions vary depending on the decision maker's characteristics (e.g., age, education, gender, etc.) Individual or collective decision-making (husband only, wife only, husband-wife jointly, males as a collective, females as a collective, all household members together) may also influence outcomes, particularly if preferences or constraints (e.g., cultural constraints) vary.

The initial step is to gain a thorough understanding of labor time and resource allocation that affects individual household member's welfare, and reflects intra-household inequalities (male/female, elderly/young), and ultimately may influence intrahousehold decision-making that may be critical to adoption and diffusion of any improved agricultural technology (as will be observed in the *ex post* study). Given this, it is vital to recover the intrahousehold decision-making structure with the inclusion of each member's preferences and production activities. The complexity of how decisions are made and which member has the final word on such decisions is assumed to be influenced by household characteristics and intra-household inequalities, which result from the intrahousehold distribution of resources and may in turn affect resource allocation within a household. Knowledge of complex household decision-making structures may help to understand farm household adoption behaviors related to new technology and influence the 'transformation' of the resultant higher soybean yields into household food security or wellbeing.

Further, dynamic effects are captured later in the dissertation in the simulation process. When the new soybean cultivars are well-adopted, the diffusion process may alter the pattern of small land-holding per capita for farm production; the potential benefits of higher returns on farm production may contribute to the formation of a land rental market. Some farm households may utilize production economies of scale through the land consolidation process.

Past studies conclude that access to land is critical to poor people worldwide because of its direct effect on households' welfare and risk-coping strategies (Holden et al., 2006; Dercon, 2002). Land resource distribution and human capital investment directly reflect economic decisions and changes in employment opportunities (Dissart and Deller, 2000). A land study conducted by the World Bank revealed that weak property rights and a history of land rental market restrictions are commonly observed in less developed countries across the world (Deininger, 2003a). In rural Africa, land rental markets are poorly functioning and typically informal (Lanjouw et al., 2001, Wouterse and Taylor, 2008). Aryal (2005) finds that the land sales market is very thin in Nepal, because only large-scale farmers are able to finance land purchases. Ilahi (1999) examines occupation change among return migrants in Pakistan. The results show that rural land markets are imperfect and the determinants of self-employment may be different from those in urban areas.

In China, the sale of farm land is prohibited but farmers are allowed to lease farm land[5]. When a well-functioning land rental market exists, rural households can make rational decisions regarding migration without the fear of losing farm land as a safety net (Zhai and Hertel, 2003). The interactions between labor mobility and land use are receiving increasing attention in rural and urban development studies (Lin, 1995; Kung, 2002; Feng and Heerink, 2008). Growing

---

[5] The Ministry of Land and Resources of China http://www.mlr.gov.cn/mlrenglish/
Land law and land management regulations (in Chinese) http://www.mlr.gov.cn/zwgk/flfg/tdglflfg/

research interest has been directed towards understanding rural-urban migration behaviors and impacts of greater openness of urban labor markets on forming rural land markets in China (Chan, 1994; Yang, 1997; Zhang and Song, 2003). Kung (2002) points out that due to the large earnings gap between off-farm activities and farm incomes, villagers tend to take the off-farm opportunity first before deciding what to do with their land. Deininger (2003b) argues that transferable land rights make it less costly for rural residents to take jobs in the nonfarm economy, which is likely to boost the off-farm sector. Other studies point out that the land rental market in rural China is emerging but is far from perfect (Yang, 1997; Yao, 2000). Kung and Liu (1997) finds that reallocation of land in China was previously accomplished through administrative channels rather than rental transactions based on individual initiative. Deininger (2003a) suggests that unclear and insecure property rights with high transaction costs limit the scope for exchange and impede long-term contracts. His study shows that informal market sales are emerging, while transactions are often limited to close relatives, when landowner confidence in property rights remains low.

As land continues to perform an important function as a social safety net for the rural population, adjustments to changes in the population have promoted land transfer or development of land rental markets in rural areas (Berger, 2001). How people make agricultural land use decisions largely depends on the policies that are in place and economic forces (Plantinga, 1996). Past studies modeling labor migration behaviors and rural land market emergence have generally assumed that 1) a rural-urban equilibrium is obtained when the agricultural rural wage is equal to the agricultural marginal productivity, and at equilibrium, the rural to urban migration rate will be zero since expected rural income equals expected urban income[6]; 2) possible farm-level labor shortages result in within-village trading of land use-rights, abandonment of agriculture on marginal land, and conversion of agricultural land to urban/exurban development (Croll and Ping, 1997, Bowlus and Sicular, 2003); 3) land rental activity is accelerated as a response to the development of the off-farm labor market (Berger, 2001); and 4) large-scale technology adoption is expected to be labor-saving.

Turner, et al. (2002), based on a survey of 215 villages across 8 provinces in China, report that less than 3 percent of overall land was leased by 1995. Deininger and Jin (2003) found that land rental markets in the poorest regions in China, were increasing, but only from 2.3 percent in 1995 to about 10 percent in 2001. Yao (2000) studied labor and land productivity heterogeneity and the openness of the labor markets in activating the land leasing market. The results show that a freer labor market[7] promotes the growth of the land leasing market in rural China.

1.3. Research Objectives

This dissertation aims to better understand rural intrahousehold resource allocation, welfare distribution, and engagement in decision-making (including engagement in decision-making related to new technology adoption) under conditions of strong out-migration pressure. Impacts of labor migration on farm labor and land rental market interactions are also measured through simulation scenarios. The research uses *ex ante* agricultural household surveys as well as key informant interviews conducted in south China in summer 2006. The household survey was designed to provide an initial understanding of crop production (including soybean production decisions and anticipated P-efficient soybean adoption decisions), food consumption preferences (including preferences for soybeans), labor time allocation, land holding behaviors, and soybean

[6] See Todaro (1969), and Harris and Todaro (1970).
[7] Due to the gradually loosening Hukou system (government administrative control for labor mobility) in China.

and soybean product markets in the south China region. GIS data on household location also were collected to enable a future second-wave *ex post* survey of the same households after introduction of the new low-P cultivars. The *ex ante* survey was conducted in three provinces in south China (Guangdong, Guangxi, and Hunan), and included individuals from villages in 5 counties (Yingde, Xintian, Longan, Laibin, and Guilin). A total 247 surveys were collected. Households were sampled from villages located along a rural-exurban-urban transition zone gradient from the more remote rural villages in Hunan Province to sites more exurban in character and proximate to urban centers, including Hong Kong. These data provide insights into household decision-making (and decision rules) regarding land, labor and technology choices. The key informant interviews conducted at each site focused on agricultural trends, rural-urban employment forces, and policy. The interview results are used to supplement the farm household surveys to determine important trends likely to affect labor time allocation, household decision-making structure, new soybean cultivar adoption, consumption and marketing behaviors across our study areas.

Specific objectives for the research are as follows:

1) The first objective is to model intrahousehold interactions in household resource endowment allocations. Individual household member's labor time allocation is examined, which is expected to contribute to insight on income sharing and intrahousehold inequalities.

2) The second objective is to reveal the intrahousehold decision-making structure and understand the underlying individual rural farm household's decision-making process under the impact of strong trends in rural-to-urban migration.

3) The third objective is to explore the dynamics surrounding household decision-making related to the formation of labor and land markets, while the anticipated new P-efficient soybean cultivar technology may alter the balance of development in both markets.

1.4. Organization of the Dissertation

The remainder of the dissertation is organized into six chapters. Chapter 2 provides a review of household models and migration theories. Chapter 3 introduces the theoretical framework comprised of the household collective model and game theory used in the simulation stage. Chapter 4 describes data obtained from the *ex ante* household survey conducted in 2006. The basic data statistics are organized into tables for an overall review of data capacity. The survey regions are presented using ArcView GIS. Chapter 5 describes the proposed methodological approach and discusses the econometric results with the model parameters analysis. The intrahousehold sharing rule is obtained to achieve research objective 1. The sharing rule results, together with other hypothesized influential variables, are incorporated in the estimation of the household decision-making structure, with particular attention paid to the impacts of migration on the individual member's role in making various farm and home production decisions (objective 2). Agent-based modeling is then used to achieve objective 3 in Chapter 6. A dynamic regime is set up based on game theory. The simulation results are presented in figures and tables, using the Recursive Porous Agent Simulation Toolkit (Repast) simulation software. Finally, Chapter 7 presents conclusions based on the econometric and simulation results, discusses limitations of the research and provides suggestions for future research.

Chapter 2

LITERATURE REVIEW

2.1. Labor Mobility and Rural-Urban Migration

2.1.1 Migration Theories: From Neoclassical Migration Theory to New Economic Labor Migration Theory

Labor migration issues have been of great interest in development economics (Harris and Todaro, 1970; Stark and Bloom, 1985; Taylor, 1999; Taylor, Rozelle and de Brown, 2003; Mendola, 2008). Since the studies pioneered by Todaro (1969) and Harris and Todaro (1970), the main stream of neoclassical migration theory has emphasized income-driven individual migration possibilities, with determinants of migration based on labor market wage differentials. Internal migration is typically the result of individuals pursuing better opportunities with an expectation of higher economic welfare in urban areas (Mazumdar, 1976). The potential migrant's expected net gain is the expected income difference between the migration origin and the destination, net of migration costs. A potential migrant favors migration when the net gain value of working at the destination is greater than working at the origin, otherwise not. With expected earnings acting as an impetus to migrate, a potential migrant will choose a migration destination to maximize expected net income (Massey et al., 1993). Net gain values are summed and discounted over time to explain long-period migration behaviors.

According to neoclassical migration theory, labor migration is caused by geographic differences in labor wage, which implies that migration will not occur without such differences. Labor markets are the primary mechanisms responsible for labor flows. As noted by Massey, et al. (1993), neoclassical migration theory relies on cost benefit analysis to predict individual's migration decision and is very feasible in terms of calculation. It results in policy recommendations to regulate both origin and destination labor markets to control or influence migration flows (Massey et al., 1993).

However, in the late 1980s and early 1990s, neoclassical migration theory was challenged by the new economics of labor migration theory (NELM). NELM studies argue that the goal of expected net income maximization may not be the only consideration for making migration decisions. The elimination of expected income differences may not result in elimination of incentives to migrate (Massey et al., 1993). One major reason is that even if migration occurs in response to expected income differentials alone, it is unlikely that the individual makes the decision without considering the gain or loss of other household members. Interactions among people, especially family members, may have prominent influence on an individual's decision-making process and result (Mincer, 1977; Lauby and Stark, 1988; Boyd, 1989). Restricted by the unitary modeling framework, ignorance of intrahousehold interactions leads to an isolated decision-making environment (Stark and Bloom, 1985). In NELM, decision-making units are no longer limited to individuals. Migration decisions are part of a household strategy instead. A typical collective decision is made to maximize household utility. In those studies, migration decisions are derived from various perspectives, such as information exchanged and compared, alternative uses and access to resources that are guided by markets (e.g., capital markets), and risk attitudes towards job markets at the destination. The NELM reflects a more complex reality than neoclassical theory. Empirically, NELM has led to socio-economic studies of social network effects (e.g., Boyd, 1989; McKenzie and Rapoport, 2007) and relative deprivation of reference groups (e.g., Stark and Wang, 2000).

2.1.2. Labor Migration and Rural Poverty in China

The rural-to-urban labor migration issue in China has been extensively studied, driven by concern over the inequality of regional development. Wage differentials between farm and nonfarm jobs encourage rural labor migrate to urban regions where labor returns are higher. Study results also reveal that work-related migration experience enhances the individual's human capital and chance of finding a higher-wage job or engaging in nonfarm self-employment (Démurger and Xu, 2010). Certainly, the continuing trend of labor migration suggests that rural households largely benefit from increasing mobility of labor (Otsuka and Yamano, 2006), although some studies stress that the loss of the rural labor force may adversely affect rural development, agricultural production, and may result in a trend toward feminization of farms (Zuo, 2004; de Brauw et al., 2008; Song et al., 2009). Among studies that measure the social gains of labor migration, the concern for rural poverty reduction highlights rural-to-urban labor migration in China in recent years.

To understand the possibility that the migration process may have only limited impacts on overcoming rural poverty across rural regions in China, Du et al. (2005) studied the relationship between household endowments and the likelihood of migration. The concern is that the rural poor may not have equal opportunity to migrate and therefore are less likely to take advantage of the rapid economic growth in urban regions through increasing labor mobility. Less education, low population density and high transportation costs in rural mountainous regions have hampered individuals' abilities to seek higher-paid jobs in urban locations. The Du et al. (2005) study results suggest that although the number of rural households with migrating members is increasing over time, the overall impact of migration has a very limited impact on the poorest households in China.

The dynamics of labor migration and inequality in rural origins are theoretically and empirically analyzed in McKenzie and Rapoport (2007). Their study, focusing on Mexico-U.S. migration, shows that the wealth level has a nonlinear effect on migration behavior. One decisive condition for the initial migrants is to afford the costs associated with migration. With initial wealth endowment above a certain level, those able to engage in migration activities gain capital accumulation faster through migration processes, which in turn enlarge the wealth gap at the origin. However, as more people engage in migration, the formation of networks lowers the migration costs for future migrants, which allows poorer households to be involved in migration. Their study results conclude that household wealth level contributes to an inverted U-shaped migration pattern. Migration will lead to the reduction of inequality at the origin with the formation of networks from past migration.

Ha et al. (2009) studied the impact of rural-to-urban migration on income inequality and gender wage gaps using Chinese Health and Nutrition Survey (CHNS) data from 100 villages in China between 1997 and 2006. Between 20 and 35 households are randomly drawn in each village during all seven survey waves. Their results confirm the inverse U-shaped pattern between migration and wealth inequality in the sending communities. Furthermore, labor migration contributes to reductions in the gender wage gap in the sending villages over time; as females actively seek nonfarm work opportunities in the urban regions across provinces, the study challenges the traditional concept that females are tied movers (Fan, 1999). However, discrimination against females in the origin is linked to discrimination in wages paid in the destination areas. Rural women are largely engaged in low skill, labor intensive and low-paying manufacturing and export-processing industries (Gao, 1994; Zhu, 2010).

Spatial patterns associated with socioeconomic characteristics are empirically analyzed to explain regional development inequalities and thus affect labor migration motivation. Poncet (2006) focused on how the individual's decisions are influenced by the costs of migration and destination labor market conditions, where costs of migration are proportional to the spatial distance. The study results find that migration costs increase significantly with distance between origin and destination areas due to the administrative restrictions in Chinese labor markets. Inter-provincial migration is more costly than intra-provincial migration. The additional expenses of moving out of the origin province to a more distant province may impede the migration ability of those living in the poorest villages. However, in Poncet (2006), aggregated migration costs decline between the two data periods of 1985–1990 and 1990–1995, reflecting the gradual relaxation of migration restrictions.

2.2. Household Models

2.2.1 Unitary Models, Bargaining Models and Collective Models

Research attention on household modeling has turned from conventional unitary models (Beck, 1960), to the game theory based household bargaining models (Manser and Brown, 1980; McElroy and Horney, 1981) and to the collective models (Chiappori, 1988a; 1992; 1997; Apps and Rees 1996; 1997). In a unitary model, a household is treated as an individual and behaves as if there is one set of preferences or that one member dominates preferences and represents the entire household. Utility is assumed to be generated through a combined labor leisure time, goods purchased in the market, and goods produced at home for the household. The utility maximization problem is based on a unitary preference and subject to a household income pooling constraint (Haddad et al., 1997). Critiques argue that in the unitary models, the implicit presumption of a household consisting of identical individuals or represented by a "dominant dictator" disregards household members' divergent interests and productive capacities. Theoretically the unitary approach ignores individualism, which lies at the foundation of microeconomic theories (Browning et al., 1994). By making large aggregations, the rich structure of microeconomic theory at the individual level is essentially lost (Chiappori and Ekeland, 2006). The income pooling property in unitary models denies the source of income or money transfer making a difference in household behavior outcomes, and thus is rejected by many empirical studies (Lundberg et al., 1997; Couprie, 2007). Furthermore, the outcomes of unitary models make little contribution toward within-household resource allocation analysis and are likely to mislead welfare distribution results (Chiappori, 1992).

To conduct intrahousehold welfare analysis, extensive studies employed household bargaining models in the beginning of the 1980s (Manser and Brown, 1980; McElroy and Horney, 1981). Various bargaining rules are applied with most commonly used Nash bargaining equilibrium concepts (Browning, 2000). However, because of the specific initial assumption of cooperative and non-cooperative game theory, Chiappori (1988b) argued that these bargaining rules are neither realistic, nor very convenient to manipulate. He suggests that unless preferences are known, bargaining concepts do not provide anything more than Pareto optimality of household decisions, so a direct Pareto efficiency hypothesis would be a much more convenient approach. Another pitfall of the bargaining models stated by Chiappori (1988b) is that when model prediction fails, researchers cannot identify whether the collective framework or the initial game assumption are to be blamed. Such identification becomes particularly cumbersome when lacking of detailed sociological data on the household's decision-making process (Vermeulen, 2002).

The assumption of Pareto efficiency is the most natural generalization of the assumption of utility maximization in a household with several members (Udry, 1996). Both household bargaining models and household collective models (Chiappori, 1988a; 1992; 1997; Apps and Rees, 1992; 1997) are considered to have advantages over unitary models for exploring interactions among household members. The generalization of both models employs the assumption of Pareto efficiency to examine intrahousehold economic behavior and determine household equilibrium allocations. Household collective models have gained more popularity, without focusing on a particular bargaining rule. When a household decision-making process results in Pareto optimality, one household member's welfare cannot be increased without decreasing the welfare of any other household members. Chiuri (2000) summarizes that both the cooperative bargaining models and the unitary models are special cases of collective models under a more general assumption of Pareto optimal household behavior.

The collective modeling framework decentralizes the household decision-making process with respect to individuals' preferences and reaches a collective outcome of individual members' rational behaviors. The interactions among household members contribute to inequality issues in resource sharing and power distribution, which are essential to welfare policy analysis. In recent years, collective models have been applied in a wide spectrum of behavioral studies: market participation decisions (e.g., Belletmare and Barett, 2006), economic evaluation of environmental resources (e.g., Smith and van Houtven, 2004), household travel and transportation planning (e.g., Recker et al., 2001; Kato and Matsumoto, 2009), household daily activities (e.g., Gliebe and Koppelman, 2002), policy analysis on child support programs (e.g., Phipps and Burton, 1996), women's employment and welfare studies (e.g., Basu, 2006), and finally behavioral response to taxation (e.g., Apps and Rees, 1999; Donni, 2003; Vermeulen, 2006). A common goal of these divergent studies (that used household collective models) is to reveal intrahousehold interactions and welfare allocation, so that households' decision-making processes are no longer treated as a "black box[8]".

2.2.2 Collective Models in Rural Household Studies

When it comes to rural farm household studies, empirical estimation of labor time allocation in collective models is surprisingly rare. Theoretically, the outcome of the decision process is fully identifiable using collective models to analyze farm households (Chiappori, 1997). Practically, in addition to pointing out the lack of suitable datasets for researchers to validate collective models of rural farm household behaviors, Donni (2004) points out that even if time use surveys are now broadly available, they are generally fragmented and unreliable for wage and income issues. Such issues typically raise concerns in rural farm household studies for developing countries, where the perfectly competitive markets assumption is invalid due to failures in labor, capital and or credit markets.

The potential problem of nonseparability complicates econometric estimations in collective models (Chiappori, 1992). In the separable framework, when all the input and output markets are complete, a convenient separability property is well-established and usually applied in past studies (Strauss, 1986; Benjamin, 1992). The separate model assumes that production decisions are independent of consumption behaviors and allows the optimization problem to be solved recursively in a simplified two-stage procedure. A household allocates total labor to maximize production profit in the first stage, and then consumption levels (including leisure) are determined based on production profit, market prices and wages in the second stage. The market wage is treated exogenously under the separability assumption and provides measures for both

[8] In Chiappori and Ekeland (2005), the black box is defined as the decision process within a household that is not known. Neither individual consumption nor intrahousehold transfers are observable.

on-farm and off-farm labor supply decisions (Lopez, 1986). However, if the labor market is imperfect, for example when off-farm employment opportunities are limited, the constraints of binding hours in off-farm labor supply may restrain the labor demand of on-farm operation (Lopez, 1986). Individuals' on and off-farm labor choices are interdependent. In that situation, households behave as if they maximize the utility function with different preferences between on and off-farm work (Benjamin, 1992). The separability between the labor supply and demand decisions is violated. The endogenously-determined shadow wage of on-farm work deviates from the off-farm market wage, even if household members work off the farm (Lopez, 1986). It is the shadow wage, rather than the observed market wage, that measures the value of time appropriately and determines the labor supply and demand choices of the household (Strauss, 1986).

Separability is generally found to be rejected in studies conducted in China (Cook, 1996; Brandt and Benjamin, 1997; Benjamin and Brandt, 2002; Bowlus and Sicular, 2003; Fleisher and Yang, 2006). There are multiple reasons for this. Firstly, a large rural population–with very limited off-farm employment opportunities in surrounding areas–cannot provide enough jobs for the excess supply of family workers (Benjamin and Brandt, 2002). Secondly, administrative control of the residency registration system suppresses labor mobility across provinces, which contributes to labor productivity inefficiency (Ravallion and Chen, 2007). Thirdly, rather than relying on market mechanisms, a restricted administrative land resource allocation and reallocation system at the village level results in inadequate land markets for agricultural production (Yang, 1997). Finally, without a functioning rural agricultural land market, small land-holding per household may directly contribute to underemployed rural labor (Rozelle et al., 1999; Kung, 2002).

2.3. Market Imperfections

2.3.1. Labor and Land Markets in Rural China

The traditional neoclassical approach has one clear, unambiguous, and verifiable prediction for capital markets: all factors that have positive prices are expected to be fully utilized (Hubbard, 1998). However, inconsistency exists between the predictions of neoclassical theory and observations from reality in the presence of market imperfections. For example, imperfections in information have fundamental effects on decisions related to investments and production scales (Hubbard, 1998; Stiglitz, 2002). Imperfections in rural capital markets may have strong influences on land investment, land transfer and transaction costs, labor-capital investment, and accessibility to market information (Benin et al., 2005; Tikabo and Holden, 2007; Ciaian and Swinnen, 2006). Market constraints, especially the availability of credit and land, influence farm production levels and further affect labor allocation and labor migration decisions (Findeis, et al., 2005; Fleisher and Yang 2006).

In rural China, the farm production scale is generally small. More than one type of imperfect capital market may coexist and create higher transaction costs (Hoff et al., 1993). Incorrect or missing prices may occur, with the extreme case of missing markets for certain production factors (Holden and Binswanger, 1998). Households with more land are likely to be more capital-constrained in crop production (Rozelle et al., 1999).

2.3.2. The Interrelated Labor Migration Policy and Land Policy in China

Rural-urban labor migration in China was depressed before 1990 because of a variety of policies and institutional barriers. In cities, a household registration system, Hukou, developed in the 1950s, restrains any migration behaviors, especially for those want to bring their family along with them. Hukou system was effectively applied in China for monitoring and controlling population movement across regions and between farm and nonfarm sectors (Shen and Tong, 1992). The school fees for a child without a proper Hukou were much higher than those for "local" children. Any decent job offers with social welfare included, requires a proper household registration within the province. Since the late 1990s, the recognition of the rural population's contribution to cities has pushed policies and regulation reforms, making it easier for migrants to live and work in the cities[9]. The increasingly mobile rural labor force sends remittances back to rural areas to assist with household's living expenses and pay for siblings' education and agricultural inputs. The marketing information about agricultural products is easier to be accessed through off-farm workers living in urban areas, which benefits farmers in new technology adoption and making production decisions on cash crops (Lohmar, 2001). Nevertheless, such reform promotes labor mobility but at the same time still operates under the household registration system. The administrative control on temporary residence cards and work permits restrict the majority migrant laborers from obtaining urban Hukou and living permanently in the cities. Hukou not only defines an individual's identity of origin, but also distinguishes social status and potentially restricts future opportunities (Chen and Selden, 1994).

Fear of losing land use rights in the rural regions creates another major concern for rural migrants. China practices a socialist public ownership of land. Land ownership belongs to all people of China, which means that the National Council exercises the right of ownership of public-owned land on behalf of the people[10]. Land in rural and suburban areas, such as housing

[9] However, it is still uncertain about the removal of the Hukou system in China in the near future. For example, in Beijing, a new government policy carried out on February 16, 2011 mandates the condition for a non-Beijing Hukou individual to purchase a house in Beijing is to provide at least five years of local tax return forms.
[10] Land Administration Law of the People's Republic of China, Chapter 1, article 2

sites and private plots of cropland and hilly land, are owned by farm collectives[11]. Village council or village leaders exercise the right of distribution of collective farm land use rights to farm households, with 30 years duration of renewable land use rights[12].

The land system was initially designed in 1958 to serve the purpose of strengthening land administration. However, such system design fails to incorporate market mechanisms. As China's economy reforms and develops, the ambiguously defined property rights and the insecurity of land rights issue become very problematic. The current land system creates obstacles in the distribution and redistribution of land resources and hampers rural economy growth. For example, in rural areas, village leaders have significant power in deciding on the redistribution of land. The incentive to abuse such power may be high (Huang, 1999; Turner, et al., 2002). As a consequence, agricultural land among households with migrating members is transferred to family relatives at no costs or little costs to ensure that some production activities take place to protect the household's land-use rights. But, on many occasions, land is left vacant if migrant households cannot find anyone to take over production. There is little incentive for farmers to sustain land productivity through land-leasing markets and in some situations, lack of commitment to scheduled farm production leads to over-exploiting soil nutrients and further declining land productivity. Overall, the lower land productivity and an inefficient land use pattern will have direct impacts on a population of 1.3 billion people's food security.

Despite the constraints, the migration wave to the cities has never been weakened. The income gap between rural and urban is too large, which attracts rural labor to move to urban areas. The majority of the migrating labor force are rural young people. After completing 9 years of mandatory education, they leave for urban areas to work for manufacturing or service

[11] Land Administration Law of the People's Republic of China, Chapter 2, article 8
[12] In 1993, China extended the agricultural land tenure to 30 years. See Liu and Wang (2005).

industries. It is very common in rural China households to have some members engaged in the migration while others remain in the villages for farming (Fan and Wang, 2008). Married couples leave their children with their grandparents. On many occasions, married women also stay in rural areas to take care of family and land.

2.3.3. Migration Decisions and Development of Land Rental Market in China

The development of both land-rental and nonfarm labor markets are likely to be critical for improving rural income and agricultural production. Rising attentions are placed in the inter-related issues of household's participation in land rental and migration in rural areas. As labor market develops, the increasing trend of rural labor migration activities facilitate the transferring of land use rights through land rental markets. Households benefit from the rent if leasing-out land or take advantage of the increasing production scale if leasing-in land. Kung (2002) suggests the emergence of land-rental market is largely due to the nonfarm labor market development in China. Farmers make decisions on nonfarm labor activities first before deciding what to do with their land. Shi et al. (2007) show that the small land-holding size per household in Jiangxi Province provides incentive for rural labor migration. The land rental market development further accelerates rural labor seeking nonfarm work in urban regions. They suggest policies should target rural region development and encourage land-rental market development to alter the pattern of labor out-migration.

However, other studies argue that the current land system in China makes administrative land reallocation flexible within a village. Farmers who are less risk-taken will fear losing the entitlement to own land or receive less fertile land and therefore hesitate in leasing-out land. As the nonfarm income is several times more than farm income, households actively engaged in nonfarm migration activities less likely will lease-in land. Li and Yao (2002) argue that as land indicates wealth level, high migration costs discourage households with small land-holding size. Households with relatively large land-holding size also are likely to stay on the farm due to the imperfect land rental market. Feng and Heerink (2008) find a negative correlation between land renting and migration. Households actively engaged in migration are less likely to participate in the land-rental market; and wherever households participate in the land-rental market, this also adversely affects migration decisions. Their study results also show that number of cattle owned by a household has a positive impact on the household's decision regarding the leasing-in of land, and those households with young or old household heads are less likely to lease-in land than middle-aged heads.

Chapter 3

THEORETICAL MODEL

3.1. Introduction

We are interested in understanding the effects of selected factors on engagement in decision-making. The development of the intrahousehold sharing rule is a critical step in explaining an individual's position in making household decisions and revealing the household decision-making structure. The intrahousehold sharing rule is defined as the share of nonlabor income (pooled non-wage income), consistent with Jacoby (1993), Skoufias (1994), and Le (2010). The sharing rule is an indication of how resources are shared within a household. However, the sharing rule alone can only provide very limited information on the intra-household balance of power and welfare. The effects from the sharing rule, wage income, and other influential factors reflect family power possessed by individual members. Such factors are hypothesized to influence engagement in making decisions that ultimately will influence economic well-being. To reflect the imperfect labor market conditions in rural China (see discussion in Chapter 1), we incorporate the shadow wage approach, first implemented by Jacoby (1993). When farmers face administrative labor market restrictions and the hours an individual can work off-farm is limited as a result, household labor supply is not determined by the market wage. Jacoby (1993) developed the farm shadow wage using the farm production function, and then estimated individual's labor supply functions using the shadow wage and 'nonlabor' income (i.e., farm profit after proper deduction of labor income; see Jacoby (1993)). The shadow wage approach bridges the estimation of farm household labor supply functions with Chiappori, Fortin and Lacroix (2002)'s household collective modeling for estimation of labor supply functions. The intrahousehold sharing rule is constructed through the parameters derived from the labor supply functions. Once the sharing rule has been established, this variable with other selected variables is used to analyze farm household decision-making structure for making particular types of decisions. Examples of decisions include those related to consumption, production, marketing and innovation. Figure 3.1 summarizes this structure[13].

This chapter presents the theory of the collective household model, with and without labor market failure considered. The collective household model follows the work of Chiappori, Fortin and Lacroix (2002), with the model recently extended by Le (2010) to include conditions of labor market failure. The latter is believed to be more appropriate for use in the rural China case, given administrative controls. The sharing rule is then introduced and the concept of decision-making structure explored; these concepts are presented in more detail in Chapter 5 where the empirical strategy is outlined. Finally, the theoretical game theory underpinnings of the simulation approach used in Chapter 6 are described, with agent-based modeling briefly discussed. The theoretical model used for the simulations assumes that households weigh the potential for land leasing against labor hiring-out decisions. That is, the household can either lease in land or hire out their own labor, if constrained by the land resource base.

[13] Potential endogeneity of the sharing rule and decision-making structure is tested for (see Chapter 5).

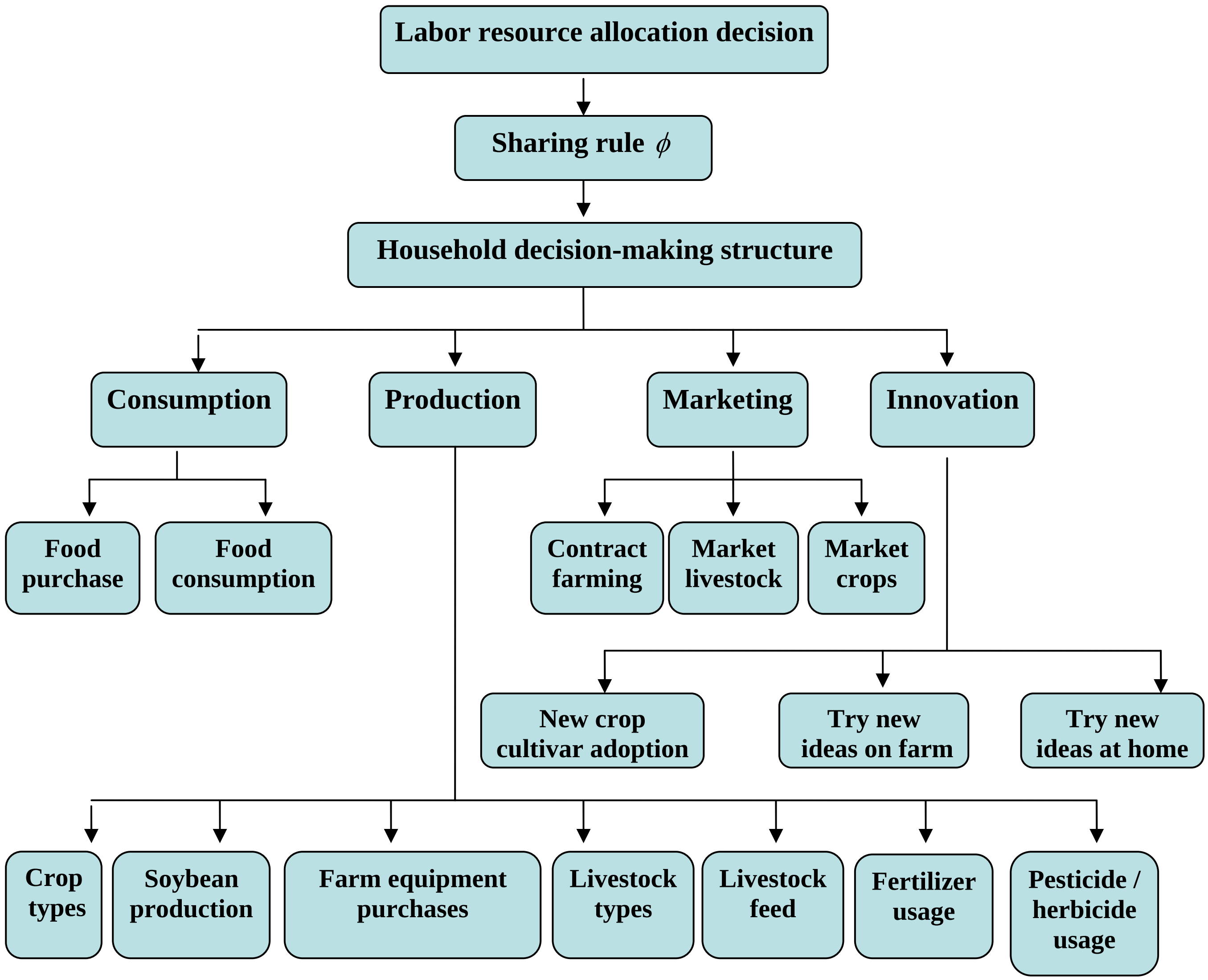


Figure 3.1 Summary of structure

3.2. Collective Household Model

3.2.1 The Basic Model Structure

Using the collective model of Chiappori, Fortin and Lacroix (2002) and Le (2010) we assume a farm household consists of two egoistic members, to keep the model simple. The household solves the following utility maximization problem (referred to as Problem 1 here):

$$Max\mu(.)U_1(C_1,l_1;z)+(1-\mu(.))U_2(C_2,l_2;z) \qquad [P1]$$

subject to:

$$Q(t_1^F,t_2^F,x;F) \qquad [P1.1a]$$

$$H(t_1^H,t_2^H;G) \qquad [P1.1b]$$

$$C_1+C_2 = pQ-p_x x+w_1t_1^M+w_2t_2^M+Y+H \qquad [P1.1c]$$

$$t_i^F+t_i^M+t_i^H=T_i-l_i \quad for\ i=1,2 \qquad [P1.1d]$$

$$t_i^M \le M_i \quad for\ i=1,2 \qquad [P1.1e]$$

$$t_i^F \ge 0 \quad for\ i=1,2 \qquad [P1.1f]$$

$$t_i^M \ge 0 \quad for\ i=1,2 \qquad [P1.1g]$$

$$t_i^H \ge 0 \quad for\ i=1,2 \qquad [P1.1h]$$

where $U_i(C_i,l_i;z)$ = individual member's utility function

$\mu(.)$ = the utility weight

C_i = a vector of own consumption goods for individual *i*, including a shared public good

Q = farm output produced

H = value of home production

x = a vector of variable inputs (e.g., seeds, chemical inputs, etc.)

F = a vector of farm fixed inputs (e.g., land)

G = a vector of nonlabor inputs used in home production (e.g., equipment, utilities, etc.).

T_i = total time endowment for individual i

l_i = time allocated to leisure by individual i

t_i^N = time allocated to nonfarm labor market by individual i

t_i^F = time allocated to farm production by individual i

t_i^H = time allocated to home production by individual i

z = a vector of human capital and other household and area characteristics

p = a vector of farm output prices

p_x = a vector of farm input prices

w_i = individual i's nonfarm market wage

Y = exogenous income

M_i = maximum amount of hours that individual *i* can work for a nonfarm or off-farm wage due to imperfections in the nonfarm or off-farm labor market[14].

The model outlined above defines the household utility maximization problem. The utility function *U(.)* is continuous, quasi-concave, and non-decreasing in own consumption and leisure. The $\mu(.) \in [0,1]$ represents the utility weight or Pareto weight associated with household members. It is the balance of intrahousehold welfare allocations between the two members. By tracing all attainable levels for μ, the intra-household welfare allocations between two members are identified and the Pareto optimal frontier is formed (Browning and Chiappori, 1998).

[14] Le (2010) introduced a labor hour constraint to reflect imperfections in the off-farm labor market.

When $\mu = 1$, the household behaves according to member 1's preferences, while if $\mu = 0$, member 2's preferences dictate. In either case, the collective model collapses into the unitary model (Chiappori, 1992).

The utility weight μ is a function of nonlabor income (y^*), marginal product of labor (*MPL)*, a vector of human capital and other household and area characteristics (z), and other distribution factors (k), such as demographics, social norms (i.e., discrimination against women), and government marriage or divorce laws or regulations (Chiappori, 1992 and Chiappori et al., 2002). The inclusion of distribution factors does not specify individual preferences and does not enter the individual's utility function directly, but directly affects the utility weights in household utility function, and therefore alters the final intrahousehold welfare allocation location on the Pareto optimal frontier (Browning and Chiappori, 1998). The consumption level and labor allocation for each member also are affected by the individual's utility weight, as a consequence (Chiappori, 1997).

It is assumed that the farm production function is continuous and twice differentiable ($Q' > 0$ and $Q'' < 0$) in labor time, variable inputs and fixed inputs. Labor time is composed of time of both family members. Farm households are assumed to be price takers in farm output markets. The home production function $H(t_1^H, t_2^H; G)$ also is assumed continuous and twice differentiable ($H' > 0$ and $H'' < 0$) in all arguments. Constraint [P1.1c] is the household budget constraint. Given a unitary price for the individual's consumption bundle, both members' joint consumption cannot exceed the sum of net farm income ($pQ(t_1^F, t_2^F, x; F) - p_x x$), nonfarm income ($w_1 t_1^M + w_2 t_2^M$), exogenous income (*Y*), and the value of home production $H(t_1^H, t_2^H; G)$. Constraint [P1.1d] is the total time available for each member. Non-negativity constraints [P1.1f~h] are imposed to allow corner solutions.

Constraint [P1.1e] defines the labor market constraint, where M_i limits the amount of hours the individual can work in the off-farm market. This is important when certain failures – e.g. imperfect information in the labor market or administrative control for labor mobility lead to high transaction costs in the labor market and off-farm opportunities are limited in surrounding areas. Le (2010) developed and tested the idea that there exists heterogeneity across farmers regarding individual's preferences or ability to overcome market imperfections. He suggests that by recognizing such diversity, analysis of household behaviors can provide different results in potentially relevant for policy. The market labor restriction is introduced as bounded by the maximum number of hours a farmer can work in the off-farm labor market. Similar to Jacoby (1993)'s test for identifying the relationship between the shadow wage and market wage, Le (2010) suggests that farmers facing no imperfections or constraints in supplying labor to off-farm work should be analyzed differently than those who do.

By substituting the farm production function [P1.1a] and home production function [P1.1b] into the budget constraint [P1.1c], the Lagrange function for the household utility maximization problem becomes:

$$L = \mu(.)U_1(C_1, l_1; z) + (1-\mu(.))U_2(C_2, l_2; z) +$$

$$\lambda(pQ(t_1^F, t_2^F, x; F) - p_x x + w_1 t_1^M + w_2 t_2^M + Y + H(t_1^H, t_2^H; G) - (C_1 + C_2)) +$$

$$\gamma_i(T - l_i - t_i^F - t_i^M - t_i^H) + \eta_i(M_i - t_i^M) + \sigma_i^F t_i^F + \sigma_i^M t_i^M + \sigma_i^H t_i^H$$

The Kuhn-Tucker first-order conditions are:

$$\frac{\partial L}{\partial C_1} = \mu U'_{C1} - \lambda = 0 \qquad \text{[P1.2a]}$$

$$\frac{\partial L}{\partial C_2} = (1-\mu)U'_{C2} - \lambda = 0 \qquad \text{[P1.2b]}$$

$$\frac{\partial L}{\partial l_1} = \mu U'_{l1} - \gamma_1 = 0 \qquad \text{[P1.2c]}$$

$$\frac{\partial L}{\partial l_2} = (1-\mu) U'_{l2} - \gamma_2 = 0 \qquad \text{[P1.2d]}$$

$$\frac{\partial L}{\partial t_i^F} = \lambda p Q' - \gamma_i + \sigma_i^F = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2e]}$$

$$\frac{\partial L}{\partial t_i^M} = \lambda w_i - \gamma_i - \eta_i + \sigma_i^M = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2f]}$$

$$\frac{\partial L}{\partial t_i^H} = \lambda H' - \gamma_i + \sigma_i^H = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2g]}$$

$$\frac{\partial L}{\partial x} = \lambda (p Q' - p_x) = 0 \qquad \text{[P1.2h]}$$

$$\frac{\partial L}{\partial \lambda} = pQ(t_1^F, t_2^F, x; F) - p_x x + w_1 t_1^M + w_2 t_2^M + Y + H(t_1^H, t_2^H; G) - (C_1 + C_2) = 0 \qquad \text{[P1.2i]}$$

$$\frac{\partial L}{\partial \gamma_i} = T_i - l_i - t_i^F - t_i^M - t_i^H = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2j]}$$

$$\frac{\partial L}{\partial \eta_i} = M_i - t_i^M = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2k]}$$

$$\sigma_i^F t_i^F = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2l]}$$

$$\sigma_i^M t_i^M = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2m]}$$

$$\sigma_i^H t_i^H = 0 \quad \textit{for i=1, 2} \qquad \text{[P1.2n]}$$

Let $U'_{C\,i} = \partial U_i / \partial C_i$ and $U'_{l\,i} = \partial U_i / \partial l_i$, comparing the pair-wise equations [P1.2a] and [P1.2b], equations [P1.2c] and [P1.2d]:

$$\frac{U'_{C1}}{U'_{C2}} = \frac{U'_{l1}}{U'_{l2}} = \frac{1-\mu}{\mu} \qquad \text{[P1.3a]}$$

which shows that the ratio of marginal utilities for both household members with regard to either consumption or leisure equals the ratio of their utility weights.

From equation [P1.2a] and [P1.2c], equations [P1.2b] and [P1.2d], we get:

$$\frac{U'_{li}}{U'_{Ci}} = \frac{\gamma_i}{\lambda} = w_i^* \textit{ for i = 1, 2} \qquad \text{[P1.3b]}$$

which shows that the individual's optimal consumption is the marginal rate of substitution between *l* and *C*, which is the ratio of the shadow prices (Jacoby, 1993). The w_i^* denotes individual *i*'s shadow wage.

According to Le (2010), labor market failure is introduced as a constraint binding hours worked in the off-farm labor market. From equations [P1.2e~2f] and [P1.2k~2m], five potential situations are derived from both members' labor supply behaviors relative to on-farm and off-farm work (Le, 2010):

Situation 1: When $M_i > t_i^M > 0$ and $t_i^F > 0$

From [P1.2k], [P1.2m], and [P1.2e],

$$\Rightarrow \eta_i = 0,\ \sigma_i^M = 0 \text{ and } \sigma_i^F = 0$$

$$\Rightarrow pQ' = w_i$$

This implies that when the off-farm labor market is complete, off-farm work is not constrained by level M_i. The marginal return from working on-farm equals the off-farm wage. An individual will participate in both on-farm and off-farm work.

Situation 2: When $M_i = t_i^M > 0$ and $t_i^F > 0$

$$\Rightarrow \eta_i > 0 \text{ and } \sigma_i^F = 0$$

$$\Rightarrow pQ' = w_i - \frac{\eta_i}{\lambda}$$

This implies when the off-farm labor market is not perfect, off-farm work is restrained by level M_i. The marginal return from working on-farm is less than the wage obtained from off-farm work. The labor market constraint leaves an individual no choice but to participate in on-farm work after reaching the off-farm work upper limit.

Situation 3: When $t_i^M = 0$ and $t_i^F > 0$

$$\Rightarrow \sigma_i^M > 0 \text{ and } \sigma_i^F = 0$$

$$\Rightarrow pQ' = w_i + \frac{\sigma_i^M}{\lambda}$$

This implies that the marginal return from working on-farm is greater than the off-farm wage. An individual prefers on-farm work only.

Situation 4: When $M_i > t_i^M > 0$ and $t_i^F = 0$

$$\Rightarrow \eta_i = 0, \sigma_i^M = 0 \text{ and } \sigma_i^F > 0,$$

$$\Rightarrow pQ' + \frac{\sigma_i^F}{\lambda} = w_i$$

This implies that when off-farm work is not constrained by the certain level M_i; the marginal return from working on-farm is less than the off-farm wage and an individual prefers working all of the work time off-farm.

Situation 5: When $M_i = t_i^M > 0$ and $t_i^F = 0$

$$\Rightarrow \eta_i > 0 \text{ and } \sigma_i^F > 0$$

$$\Rightarrow pQ' = w_i - \frac{\eta_i}{\lambda}$$

This implies that when the off-farm labor market is not perfect, off-farm work is restrained by level M_i although an individual has strict preferences for working off-farm only. The marginal return from working on-farm is less than the wage obtained from off-farm work, nevertheless.

Similarly, following Jacoby (1993), by comparing individual member's off-farm work and home production through equations [P1.2e], [P1.2g], [P1.2k], [P1.2l], and [P1.2n], another five potential situations are derived to illustrate the individual time allocation decisions toward off-farm work and home production. When the circumstance of labor market failure is introduced as a constraint which binds hours working off-farm, the value of the marginal product of labor in farming (MPL) is defined in the first-order conditions as the farm shadow wage (w_i^*):

$$w_i^* = U'_{li} / U'_{Ci} = p\, \partial Q / \partial t_i^F = \partial H / \partial t_i^H = w_i \quad \text{if } M_i > t_i^M > 0 \text{ and } t_i^F > 0 \qquad \text{[P1.4a]}$$

$$w_i^* = U'_{li} / U'_{Ci} = p\, \partial Q / \partial t_i^F = \partial H / \partial t_i^H < w_i \quad \text{if } M_i = t_i^M > 0 \text{ and } t_i^F > 0 \qquad \text{[P1.4b]}$$

Based on Le (2010), the above conditions are applicable to situations in farm production or home production relative to off-farm production. It states that if an individual's off-farm labor allocation is not constrained by level M_i, then the marginal return of working on-farm/home production is the same as working off-farm, and the MPL of working on-farm/home production equals the market wage. However, when the labor market imposes an upper limit on how many hours an individual can work for a wage, the marginal return for on-farm work/home production is no longer the same as working off-farm.

Finally, let h_i denote the total labor work time by individual *i*, which is the labor time spent on all production activities, including farm production, nonfarm production, and home production. Then, as shown in Jacoby (1993), the household nonlabor income is:

$$y^* = pQ(t_1^F, t_2^F, x; F) - p_x x + w_1 t_1^M + w_2 t_2^M + Y + H(t_1^H, t_2^H; G) - w_2^* h_1 - w_2^* h_2 \qquad \text{[P1.4c]}$$

The above equation shows the household nonlabor income in a static agricultural household model, with the opportunity cost of labor time properly deducted. In cases when a household member works exclusively off-farm, the time spent on household work is valued at the market wage.

3.2.2. Introducing the Sharing Rule

In principle, the implicit rule of intrahousehold sharing essentially relates to the distribution of household resources and may be directly interpreted as intrahousehold inequality (Couprie, 2007). Chiappori (1992) presents the basic idea for the sharing rule that "*for each "egoistic" member, changes either in household nonlabor income or in the spouse's wage can have only an income effect; specifically, they will affect the member's behavior only insofar as her share of nonlabor income, as defined by the sharing rule.*" A straightforward approach to recover such inequality is by observing private goods and public goods consumptions, which can be explained as the outcome of a sharing rule (Doss, 1996; Chiappori, 1997). However, the practical problem arises that both individual private and public good consumptions are simply not observable in a household with more than one member (Lise and Seitz, 2004).

To overcome this problem, some researchers suggest using alternative methods to estimate sharing rules. Browning, Chiappori and Lewbel (2003) and Couprie (2007) assume that an individual female's consumption preference in a couple is similar as to before marriage. By obtaining data from single's consumption, the sharing rule for married couples thus can be identified. Vermeulen (2006) assumes a particular sharing rule functional form without knowing individuals' private consumption levels. This method was initially introduced by Van Soest (1995). The main idea is to opt for a discrete-choice model. Rather than use continuous real positive numbers for labor time, the discrete choice model groups an individual's working hours into categories and assumes an individual made a choice in a discrete set of labor supply options. By comparing a number of labor supply options, a household chooses certain level of labor supply that yields the highest utility from various income-leisure combinations. The advantage of using a discrete choice model is that it enables a direct comparison of different of tax policies based on the limited discrete number of income-leisure combinations. Instead of obtaining individual consumption data, Kalugina, Radtchenko and Sofer (2009) consider the discrepancy in self-rated income scales[15] reported separately by husband and wife, which reflects inequality in household bargaining and sharing. The estimation procedure combines both husband's and wife's labor supply functions with an inequality index constructed through the individual's own perception of wealth. By assuming self-rated wealth level between husband and wife are the same reflects an equal income-sharing, the spouse reported higher wealth level controls more "bargaining power" within a household. Caiumi and Perali (2001) investigate how total household expenditures are shared between husband and wife as family size expands. Since children affect the allocation of time between labor and household work for both spouses, the cost of children can be decomposed into husbands' and wives' relative contributions to market goods, household products and leisure consumption. Therefore, the cost of children also describes intrahousehold exchanges of goods and leisure. They estimate the sharing rule equation in terms of the leisure time associated with children at different ages for both spouses as influenced by market wages. Home production is incorporated in the labor time allocation.

In this study we extend the method of Chiappori, Fortin and Lacroix (2002) described below. Labor time is one typical example of an exclusive and assignable good (Chiappori,

[15] To measure individual budget, the questionnaire asks individuals to evaluate their economic situation from the poorest to the richest in nine categories. The assumption made is that household members provide the same answer to this question if they receive the same share (one-half) of household income.

1997[16]). Unlike private consumption, private labor time can be observed independently. The existence of assignable goods provides prediction for intrahousehold allocation of resources and therefore the sharing rule describes the process of intrahousehold negotiation in labor time allocation. Using labor time as an assignable good has the advantage of being empirically tractable (Chiappori, 1992; Bourguignon and Chiappori, 1992; and Browning and Chiappori, 1998). The sharing rule is up to an additive constant from the sole observation of labor time (Chiappori, 1992).

3.2.3. Identification of the Sharing Rule

Let's further assume that the abundance of public goods from home production[17]. The public goods consumption effect is through an indirect income effect only (Couprie, 2007). In other words, an agent's consumption of domestically produced public goods affects neither the sharing of private goods nor leisure time. So a weak separation between the public goods (*H*) and the private goods (c_i) for *i=1,2* introduces an agent's sub-utility $u_i(.)$, which is conditioned on public goods consumption but consists of private goods consumption and leisure only (Couprie, 2007):

$$U_i(C_i, l_i; z) = V_i(u_i(c_i, l_i; z), H; z)$$

This condition guarantees that the marginal rate of substitution between nonpublic goods is independent of the public goods consumption level (Browning, 1994). So the sub-utility

---

[16] Chiappori (1997) states "A good is exclusive when it is consumed by only one member; a typical example is labor supply (or leisure), at least insofar as it is not a public good for the household." P.42.

[17] As explained in Couprie (2007), the public goods consumption is not assumed to be efficient. In other words, Pareto optimal frontier is formed by altering private consumption and leisure only. The public goods' consumption will not directly affect the private consumption and leisure trade-off, but through income effect only.

function is to maximize each agent's own welfare, $Max\ u(c_i, l_i; z)$, subject to a budget share on private expenditure.

Recovering the individual member's utility weight is another obstacle to solve the collective model. Empirical studies suggest mapping all arguments contained in the utility weight $\mu(.)$ through the rule of sharing. Then the sharing decision is represented by some function $\phi(w_1^*, w_2^*, y^*, k; z)$, such that $\phi_1 = \phi$ and $\phi_2 = y^* - \phi$. The function ϕ defines the sharing rule that, according to the efficiency assumption, household members agree upon the amount of income that s/he is allowed to spend. Chiappori (1997) proved that by the second fundamental welfare theorem, under the Pareto optimal assumption, each household member solves a decentralized problem; a sub-utility function decentralizes the problem 1 by maximizing each agent's own welfare subject to a budget share on private consumption, yielding Problem 2:

$$Max\ u_i(c_i, T_i - h_i; z) \qquad [P2]$$

subject to:

$$c_i = w_i^* h_i + \phi_i \quad for\ i = 1,2 \qquad [P2.1a]$$

$$c_i \geq 0 \quad for\ i = 1,2 \qquad [P2.1b]$$

The Marshallian labor supply is (Chiappori, Fortin and Lacroix, 2002):

$$h_1 = h_1(w_1^*, \phi(w_1^*, w_2^*, y^*, k, z); z) \qquad [P2.2a]$$

$$h_2 = h_2(w_2^*, y^* - \phi(w_1^*, w_2^*, y^*, k, z); z) \qquad [P2.2b]$$

Once the functional form of labor supply is defined, the sharing rule can be obtained by inverting the labor supply functions (Chiappori, 1997; Chiappori, Fortin and Lacroix, 2002).

According to Chiappori, Fortin and Lacroix (2002), any changes in agent 1's market wage, nonlabor income and distribution factors that have an income effect on agent 2's behavior is only through its effect on the sharing rule. Thus, identifying the partial derivatives of the sharing rule is through the marginal rates of substitutions of shadow wage and nonlabor income, as well as distribution factors and nonlabor income (see Chiappori, Fortin and Lacroix (2002) for mathematical proofs).

3.3. Household Decision-Making Structure

The amount of time the individual supplies to farm production is one among many other decisions made by farm households. Other decisions, such as crop production (e.g., what crops to grow, what chemical inputs to apply, where to market crops, and new crop cultivar adoption), livestock production (e.g., what livestock to raise, what to feed livestock, where to market livestock), investments (e.g., purchasing farm equipment, engagement in contract farming, and whether to try new ideas or not), or even what to have for family dinner may reveal quite different household decision-making structures. Studies of household decision-making structures have broad applications: for example, family role structure and decision strategies are examined to predict the likelihood of family purchasing behavior (e.g., Corfman and Lehmann, 1987; Lee and Beatty, 2002), travel and holiday destination choices (e.g., Wang et al., 2004; Zhang et al., 2009), and residential location choice behaviors (e.g., Borgers and Timmermans, 1993), to name a few. Farm household decision processes, potentially important for understanding decisions related to new technology uptake, are still under-researched. Although household collective models provide useful tools for empirical studies to recover the intrahousehold sharing rule, which likely provides a good indication of resource allocation among household members, *the linkage between income sharing and individual member's role in making economic decisions is missing in past studies.*

In understanding and predicting a household's perception of farm practices and new technology adoption, which member has the final word? Who spends the time and energy in what type of production? When other nonfarm income sources are available, who is responsible for farm production decisions? All of those questions are directed to the intrahousehold behavioral analysis. In our study, the likelihood of which household member (husband or wife) makes a decision or whether decisions are made jointly (e.g., between husband and wife, among adult males or adult females in the household, or by all members of the household together) is hypothesized to be predicted by the influence of the sharing rule, labor wage, on-farm work, off-farm work, home production, work distance (by different household members), presence of other household members, and remittances. Three specific research questions will be examined:

RQ_1: What is the impact of the sharing rule on intrahousehold decision-making structure? Many socio-economic studies agree that who controls resources makes a difference in intrahousehold allocation (Caiumi and Perali, 2001; Lise and Seitz, 2004; Bourguignon et al., 2006) but whether individuals are involved in the household decision-making process and if their involvement is potentially affected by the sharing rule needs to be clarified. It is recognized that simply obtaining the sharing rule will not provide us complete information that affects the *outcomes* of household decisions. Rather, we seek empirical verification of whether the sharing rule impacts *who* is involved in the decision-making processes.

RQ_2: Will household members who spend time on home production gain more power in making farm production decisions? In developing the collective modeling framework, Apps and Rees (1997) emphasize the importance of taking into account home production, so that leisure time consumption is not overstated by misinterpreting home production as leisure time. Other studies suggest that ignoring home production may bias the modeling results and invalidate the welfare inequality analysis (i.e., Couprie, 2007; Donni, 2008; Rapoport, Sofer and Solaz, 2009). Yet, no previous studies have examined if the time spent on home production influences the individual member's decision-making power in other production activities, in this case farm production. If labor time spent on home production alters intrahousehold resource allocation among members, then it is reasonable to expect that his/her home production behavior can significantly affect his/her involvement in making farm production decisions, especially in a farm household context.

RQ_3: What is the impact of an individual household member who works further away on household decision-making structure? Can we assume that the farther away an individual works from home, the less likely he/she will be making decisions alone, since other household members are expected to be more likely to be involved as a result? We would like to understand the impact of labor out-migration for off-farm employment on intrahousehold decision-making structure from measures of off-farm distance. In this study, it is also critical to understand migration impact on household members' involvement in making decisions on new technology adoption, providing better prediction of the adoption and diffusion of the new P-efficient soybean cultivars.

3.4. Simulation

3.4.1. Households Land Leasing and Labor Hiring Decisions

It is a general belief that the large income gap between on-farm and off-farm work provides strong incentives for farmers to seek off-farm work opportunities. Thus, we assume that the marginal returns to off-farm work exceed that to on-farm production; as a result, farm households are assumed to make the off-farm work decision first before deciding how to use the land resource and the remaining labor.

Land-leasing in rural south China is still an informal market. It lacks the market mechanism to provide land leasing information among villages or households within villages. Farmers are increasingly comparing the returns from farm work to potential earnings in nonfarm work. This comparison encourages farmers to raise their productivity in farm work and helps to form labor and land markets in rural areas (Lohmar, 2001). There are households that still consider agricultural production as their primary income source. This may be caused by the limited ability for finding off-farm work in urban labor markets (e.g., constraints imposed by age, education, gender, etc.), or personal/family preference-related reasons (e.g., need to take care of children, or elderly people, health conditions, etc.).

Limited by village rules and imperfect information in the rural land rental market, households usually only lease their land to their relatives or to someone they know (Deininger and Jin, 2005). The reason behind it is that those households fear losing their use rights to the entitled land once the village council reallocates land (Krusekopf, 2002). Land is still considered as important capital for those households having an insecure urban living.

Define farm households as the basic agents; an agent's objective is to find an effective way of using land and labor to maximize household farm income. Agents have abilities to learn from each other. To improve household farm income, an agent compares current own payoff with payoff received by surrounding neighbors and then copies the strategy from the most successful neighbor. A classical game-theoretic approach to this issue can be used. There are two types of agents: one has extra land or demand for labor, namely a land-type agent. Another has extra labor or demand for land, namely a labor-type agent. The benefit of an agent leasing-in land is to utilize economies of scale for own farm production, but the agent's initiative of leasing-in land may be offset by bearing higher risks in farm production. The benefit of an agent hiring-out labor is that less investment is required and thus taking less production risk than leasing-in land. But being hired as seasonal labor means receiving fewer payoffs and no economies of scale are obtained without increasing farm size. The land rental contract is signed on a yearly basis compared to seasonal farm labor hiring. Therefore, the fixed-term land contract could limit the family laborers off-farm activities for both agents agreed on a land leasing contract. The land leasing-out agent will not be able to accommodate household members who lose their jobs in the cities and return to farming, without leasing-in land from another agent or asking the returned member to find seasonal farm work on another farm. The land leasing-in agent will not be able to have the flexibility of allowing its household members to migrate unless hiring-in labor from another agent. The conflict of interests occurs when the land-type agents realize that to lease out land and to receive a lump sum payoff for land will make them better off than hiring-in labor to work on their land. But labor-type agents prefer getting a payoff by being hired in rather than leasing-in land.

3.4.2. Game Theory Approach

The specific land leasing and labor hiring strategies is analogy for the classic coordination stag-hunt game. According to the French philosopher Jean-Jacques Rousseau's story, in a stag-hunt game, hunters each have the choice of hunting deer or hare. To hunt deer, each hunter has to remain faithful to his post and cooperate with other hunters to succeed. "*But if a hare happened to pass within reach of one of the hunters, we cannot doubt that he would have gone off in pursuit of it without scruple.*" If a hunter decides to hunt the passing hare, he would abandon his post and waste the trap set up for hunting the deer for the other hunters. According to Rousseau, this describes the conflict of between hunting deer and hare. Hunting hare doesn't require the amount of social cooperation and thus is easy to obtain. But a hare is worth less than a deer.

Skyrms and Irvine (2001) provide two examples of the conversion of the stag-hunt game to illustrate other social cooperation phenomena. One example is from David Hume who describes two men rowing a boat. If one man decided not to row, then the other man's rowing effort is in vain, since the boat will not move without joint efforts. But if both men corporate, both men will benefit. Another example is the meadow-draining problem of Hume's Treatise. Two neighbors wish to drain a commonly-possessed meadow. Either neighbor fails his part will lead to abandon of the project. But each neighbor must choose an action without knowing the choice of the other.

The example below can be used to illustrate the game. In a two-hunter stag-hunt game, suppose the payoff matrix is given as follows:

Hunter 2

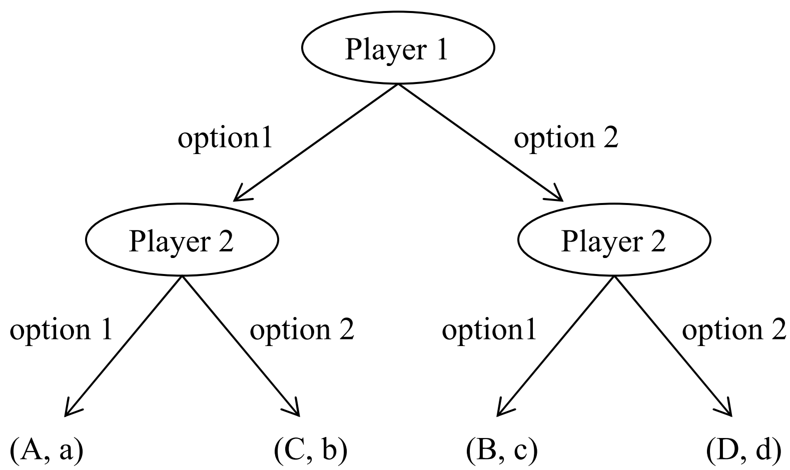
		deer	hare
Hunter 1	deer	5, 5	0, 4
	hare	4, 0	2, 2

The payoff dominant strategy for both hunters hunting for deer (5, 5) is Pareto superior compared to the other strategies and results in Nash equilibrium. This means coordination is achieved and lead to the best payoff for both hunters. But that is not the only Nash equilibrium in this game. Uncertainty plays a role in both hunters' decisions, since either hunter has no knowledge about the other's choice. The more uncertainty hunters have about the actions of the others, the more likely they will choose the strategy that avoids the zero payoffs (see example above). Therefore, both hunters may end up choosing hunting for hare simultaneously (2, 2), which is risk dominant over other strategies and leads to another Nash equilibrium.

A more generalized two-player two strategy one-short stag-hunt game decision structure is:

Player 2

Player 1	option1	option2
option1	A, a	B, c
option2	C, b	D, d



To ensure the cooperation strategy pair (option 1, option 1) payoff dominates over any other strategies, the payoff matrix shows that when $A>C\geq D>B$ and $a>c\geq d>b$, the strategy pair (option 1, option 1) is a Nash equilibrium. But as hunting story describes, such cooperation between players may fail in the absence of credible commitments. Explained by Skyrms and Irvine (2001) when hunters have doubts about each other's faith in hunting deer, the appearance of a hare provides a chance to pursue a least-risky option: strategy pair (option 2, option 2), which also leads to a Nash equilibrium. Player1's decision in choosing an option depends on the probability of player 2 choosing the same option. That is player 1 calculating the risk factor, p, which is the probability player 2 will choose option1 (deer) given the expected payoffs between strategy pair (option 1, option 1) and strategy pair (option 2, option 2) are indifferent. The expected payoff to player 1 to choose option1 given the probability of p that player 2 will choose option 1 is $E[\pi_{option1}] = pA + (1 - p)B$. The expected payoff to player 1 to choose option 2 given the probability of p that player 2 will choose option1 is $E[\pi_{option2}] = pC + (1 - p)D$. Let $E[\pi_{option1}] = E[\pi_{option2}]$, $p=(D-B)/(A-B-C+D0)$. The value of p is the risk factor for player 1 choosing option1. If player 1 believes the probability of player 2 will choose option 1 is less than p, then the best strategy for player 1 is to choose option 2 (Skyrms and Irvine, 2001).

In the hunting case, the best strategy for one hunter is to hunt deer if the other hunts deer, and to hunt hare if the other hunts hare. In our study, if agent *i* would like to choose the land leasing then the best strategy for agent j is to negotiate the rental price with *i*. We assume that the payoffs from land leasing are greater than the payoffs from labor hiring for both agents. However, there are multiple reasons for either agent to hesitate in choosing the land leasing option. Here are some common thoughts from both agents' point of view: Firstly, the land leasing-out agent may suspect the other agent's production activities will over-exploit soil nutrients which may lead to decreasing of land productivity. Secondly, the land leasing-out agent has doubt because leasing out land may jeopardize his entitlement to the land rights for the administrative reallocation of land in the near future. Thirdly, the land leasing-in agent may think the plot of land (i.e., size, soil texture, land slop, etc.) may not be suitable for his production needs. Fourthly, the land leasing-in agent may feel uncertain about realizing higher productivity after increasing the production scale. Fifthly, some possible dispute may rise during or at the end of the leasing terms, which will cause the land-leasing out agent to fail to claim his land back or the land leasing-in agent cannot continue his production plan. And lastly, the price negotiation will not always reach an agreement, because agent *i* does not want to lower the price or *j* does not want to raise the offer price. As a consequence, the lack of commitments from both agents may result in an alternative option: agent *i* will consider hiring labor from *j*. In either case, the agreement between agents will reach Nash equilibrium. It is assumed that labor markets in villages are better developed than land markets.

3.4.3. Agent-based Modeling

The fundamental purpose of ABM is to provide insights into agent's behavioral analysis and interactions with the surrounding environment. The most distinct feature of ABM is that it is considered as a bottom-up approach, which is based on the behavior of each individually-defined agent. Group behavior is then observed from the aggregation of all agents by categories instead of induced from theory (Tesfatsion, 2002).

ABM studies cover a wide spectrum of science from complexity in artificial life applications (Epstein and Axtell, 1996; Menczer and Belew, 1996) to the flocking behavior of animals (Reynolds, 1987); from social learning abilities and diffusion through networks (Curran and O'Riordan, 2007; Izquierdo, et al., 2008) to language evolution (Laine and Gasser, 2003; Bartlett and Kazakov, 2004); from human movement patterns (Helbing, 1992; Helbing and Molnar, 1997; Batty, et al., 1999) to people and environment/resources interactions (Deadman and Gimblett, 1994; Parker and Meretsky, 2004; Berger et al., 2007); from disease spread (Eubank et al., 2004) to national defense (Moffat, 2000; Cioffi-Revilla and Gotts, 2003). The ABM approach is not isolated from the theoretical frameworks of economics. Related economic approaches include game theory (Peffer and Llacay, 2007; Takadama, et al., 2008), role playing games (Castella, et al., 2005; Barreteau, et al., 2001), optimization (Gjerdrum et al., 2001), spatial analysis and GIS (Itami and Gimblett, 2000; Brown, et al., 2005; Evans and Kelley, 2004), cellular automata (Berger, 2001; Dijkstra, et al., 2000), linear programming (Earl and D'Andrea, 2002; Schreinemachers and Berger, 2006), and genetic programming (Chen and Yeh, 2001; Luke and Spector, 1996).

A growing number of studies employ an agent-based approach to model a variety of issues in land use and land cover (LULC) change influenced by complex interactions in the context of spatial and social interactions. Agents with conflicting interests interact to make decisions on their desired locations and contribute to the formation of optimal land use patterns (Otter et al., 2001; Sasaki and Box, 2003). Parker and Meretsky (2004) link externalities and landscape patterns to explore conflicts between urban and agricultural land uses. Evans and Kelley (2004) studied the scale effects of household decision-making on land use patterns. Irwin and Bockstael (2002) address the spatially distributed land parcel owners' (agents') behavior related to subdividing their land for development and the effects on low-density urban sprawl. Irwin, et al. (2003) use individual land use conversion decisions at a disaggregate level to identify factors that drive changes in land types.

There have been limited attempts to date using ABM to explore labor migration behavior in socioeconomic studies. Makowsky, et al. (2006) applied an agent-based model to simulate scope and impact to understand disaster-driven migration. Silveira, et al. (2006) emphasized on social learning by imitation through migration experience, combining the Harris-Todaro model of the rural-urban migration process and the agent-based approach.

Several recent studies have examined technology adoption and diffusion processes using ABM. Berger (2001) applied agent-based models to agriculture to address the diffusion of innovation and adjustments in resource use. Schreinemachers and Berger (2006) model the learning process and farm household technology adoption behaviors in an agricultural production, consumption and investment system. Darmon and Torre (2004) explore agents' expertise and learning patterns when using new products in commercial markets.

In many domains, agent-based system models compliment equation-based models (EBM) to identify system variables and evaluate outcome complexity. Both agent-based and equation-based approaches simulate the system by constructing models and running simulations based on the constructed models. The ABM models consist of a set of agents that encapsulate the behaviors of the various agents who comprise the system. Berger (2001) argues that besides conventional simulation models based on mathematical programming have tendency to over-specialization and generate aggregation errors, ABM has advantage over EBM in incorporating interactions among agents. Epstein and Axtell (1996) state that ABM is superior to EBM when anticipated equilibria are impossible to compute or unstable or only exist asymptotically. ABM is also considered a better choice than EBM when some parameters are unidentified and the model is partially insolvable.

Chapter 4

SURVEY DATA

4.1 Cross-province Survey in Rural South China

In 2006, the socioeconomic team, in close collaboration with the Root Biology Center at South China Agricultural University (SCAU), conducted an *ex ante* baseline socioeconomic household survey and face-to-face key informant (KI) interviews in selected villages in rural south China. The baseline household questionnaire was designed to provide an initial understanding of soybean production, other crop production, and anticipated phosphorous-efficient soybean adoption decisions; food consumption preferences with particular attention to soybean home consumption and interest in soybean product (e.g., tofu) consumption; labor time allocation; and land holding and land use behaviors. KI interviews assessed 1) soybean and soybean product markets in the south China region, 2) regional and local trends that could affect the demand for or supply of soybeans, and 3) adoption and diffusion of the P-efficient cultivars.

Whenever possible, face-to-face interviews using baseline household questionnaires were conducted (separately) with an adult male and female respondent in the household, to allow for the possibility of different perspectives that could affect cultivar uptake. Questions explored 1) household interest in new P-efficient soybean varieties, 2) resource allocation to farm and off-farm work, 3) rural-to-urban short-term (temporary) and long-term (permanent) migration behaviors by migrant age and distance to urban centers, and 4) intra-household decision-making structure, among other questions. The surveys provide rich data to characterize rural agricultural households in south China; these data are absent from national household census data for China. Further, for each household, GPS latitude and longitude data were collected to facilitate a second-wave *ex post* survey of the same households after introduction of the new P-efficient cultivars. Collection of *ex post* data will allow for assessment of adoption and diffusion of the new soybeans in the region and an evaluation of implications for household income and other outcomes of specific interest (e.g., changes in labor time, consumption levels, etc.).

The survey was conducted in three provinces in south China (Guangdong, Guangxi, Hunan), and included agricultural households from 32 villages in 5 counties (Yingde, Xintian, Longan, Laibin, Lingchuan). Given strong trends in the region toward rural-to-urban migration of the young and middle-aged and the expected importance of remittances to those remaining in rural areas, households were interviewed in selected villages along a rural-exurban-urban gradient from the more remote rural villages in Hunan Province to sites more exurban in character and proximate to urban centers. A total 247 surveys were collected.

Following a brief discussion of background data and major trends identified through the KI interviews for those villages where surveys were conducted, this chapter includes a focused discussion of the following:

1. The extent to which survey respondents living in the villages anticipate that they will adopt the new soybeans, current soybean consumption patterns, and anticipated distribution of the 20-30% yield gains expected from uptake of the P-efficient soybean cultivars (i.e., the split among home food consumption, feed for own-farm use, and marketing for food or feed).

2. Trends with the potential to influence adoption of the low-P soybeans, focusing on a) out-migration of the next generation and b) the potential to help feed the growing elderly population left in China's rural areas.

3. Simulations of adjustments in land and labor markets in south China that could result under different conditions (e.g., perfect vs. imperfect labor markets, different gaps between

urban and rural wages, greater profits from soybean production reflected in land value, and flexibility in land leasing).

4.2 Survey Site Characteristics

Key informant interviews were undertaken in the villages where the surveys were conducted, and involved local government officials, experts in extension, agricultural academic researchers, village leaders, and soybean brokers; key informants provided background data to supplement secondary data on soybean markets in south China and trends that could affect uptake. The interviewees expressed their understanding of the local economy, labor migration trends, and how most households earn their livelihoods. Unbalanced economic growth across regions is a major cause of domestic labor migration, especially as embedded in differences in rates of rural-urban development, as found in many developing countries. Geographic labor mobility promotes efficient labor resource allocation for societies, and labor migration also allows individuals and households the ability to maximize their utility or satisfaction. Figure 4.1 presents locations of the survey sites mapped with Arcview.

Descriptions provided by key informants are summarized below for the five counties where interviews were conducted. An assessment across sites shows that the closer a county is to major urban centers, especially Hong Kong and Guangzhou (capital of Guangdong Province and the top migrant urban destination, according to survey results), the relatively less important crop income is relative to income from nonfarm employment.

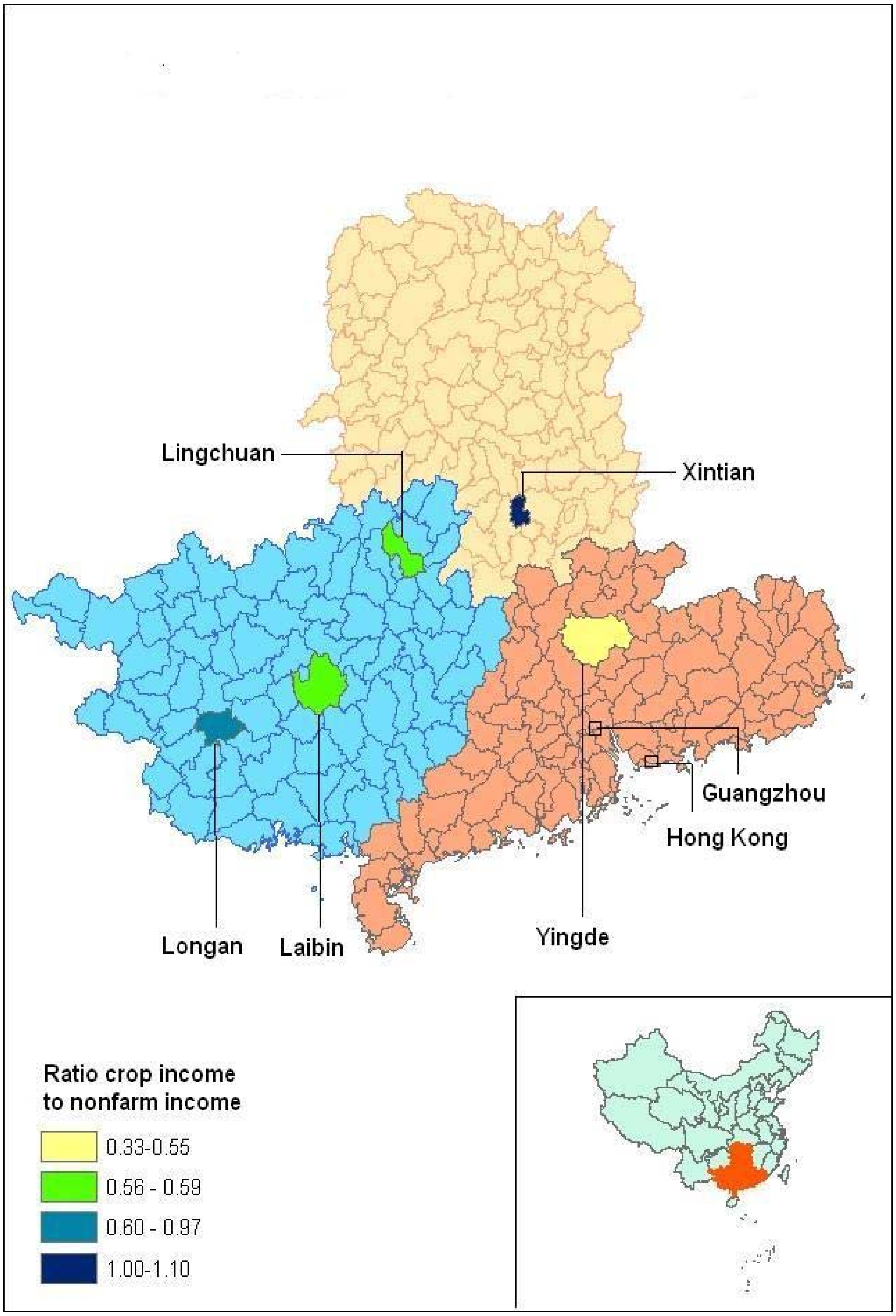


Figure 4.1 Map of survey sites and indicating the relative importance of crop income vs. nonfarm income, 2006

KI Interview summary: Yingde County, Guangdong Province. Yingde County is located 138 km from Guangzhou City. The economy in Guangdong Province has supported the country's largest GDP since 1989, and its 13.1 percent annual average GDP growth rate ranks highest among all provinces in China. The economic structure in Guangdong has resulted in development of special economic development zones with massive scales of manufacturing industries, providing a very large number of employment opportunities for migrating workers. International trade is active and well-structured. Guangzhou has China's fourth largest harbor, which is also the largest harbor in south China. Given very strong growth in nonfarm employment in the province, the agricultural economy is shrinking there.

Yingde County is located in a mountainous area, with the local economy dependent on agricultural production, including rice, tea, soybeans, peanuts (for oil), and sugarcane, as examples. The total arable land size is 99,643 hectares and the total population in 2000 was 810,446[18]. Local farmers have tried to transition from traditional crop production to cash crop and fruit production. Fruit trees recently have become more popular among farmers, outpacing rice production. Fruit production in Guangdong has a reputation for high quality.

KI Interview summary: Xintian County, Hunan Province. Xintian County is located in Hunan Province, which is approximately 450 km from Guangzhou City. The county size is 104,200 hectares and had a population of 358,831[19] in 2000. It is one of the poorest counties in China. Agricultural production is the most important economic sector in the county's economy. Agricultural production accounted for 80% of total production value in Hunan in 2004. Agricultural household annual income was only 1518 yuan (US $190) per person in 2004, 4.6% higher than in 2003, according to the Xintian County 2004 Economy Growth Report.

---

[18] Based on the fifth national census data in 2000, National Bureau of Statistics of China.
[19] Based on the fifth national census data in 2000, National Bureau of Statistics of China.

Farms mainly produce rice, tobacco, soybeans, and sweet potatoes. Sweet potatoes have great potential for the processing industry for products including alcohol and bio-fuel. Rice production requires the highest investment of about 140-150 yuan/mu and poses the greatest pest problems. For tobacco, fertilizer is increasingly used to ensure a good harvest. For soybeans, fertilizers are not heavily applied. Before sprouting, soybeans need a layer of surface fertilizer. After sprouting, another layer of fertilizer is applied at the plant roots. Later on, as the beans grow, fertilizer is sprayed on the leaf surface. In 2005, taking into account all three production seasons (spring, summer, fall), the total production scale of soybean was about 3,000 hectares, with a total production of 7,255 tons.

The local soybean cultivar 'May yellow' is dominant in Xintian County, and contains high levels of protein compared to other local soybean cultivars. Livestock production is generally not profitable, even if no labor costs are taken into account. Swine, poultry and some sheep are produced. Every household raises more than 10 pigs yearly on average, with pigs usually sold to Guangdong Province. Before 1995, swine production was profitable. But in recent years, Guangdong has increased its own swine production scale, and the swine selling price has declined over time. Currently, approximately only 20-30% households in the county are still keeping swine. Chicken and ducks are raised in a small production scale. Not many households keep sheep. Between 40-50% of Xintian's labor force is engaged in off-farm jobs, with off-farm employment generating higher incomes than farming. Farming on average brings in 1,500 yuan of income per year per laborer, while an off-farm job can bring in 7,000-8,000 yuan[20] of income annually per laborer. For those who do not have the opportunity to be hired into off-farm jobs, farming is still their most important income source (with the possible exception of remittances).

[20] 1 US $ = 7.99 yuan in 2006

KI Interview summary: Longan, Laibin, and Lingchuan Counties, Guangxi Province. Guangxi Province also is adjacent to Guangdong Province. Three regions in Guangxi were surveyed including the counties of Longan, Xingbin and Lingchuan, which are on average 1,314 km distance from Guangzhou City. The total arable land size is 33,200 hectares, 358,400 hectares, and 223,000 hectares, respectively[21]. The total population in 2000 was 313,306, 839,790, and 318,136 in the three counties, respectively[22].

Soybean production is possible in three seasons spanning February through November. Longan County produces mainly summer soybeans from mid-June to the end of November. Laibin County has two soybean production seasons: the spring soybean season from February to July and the fall season from mid-July to November. Agricultural households in Lingchuan County are more likely to produce fall soybeans. The soybean growth periods vary depending on seasonal temperature and rainfall, and the three regions have different dominant soybean cultivars. Soybean production is more concentrated in the northern part of Guangxi Province. Soybeans are considered a traditional crop. A high demand for sugar processing in Guangdong Province has driven the expansion of sugarcane production in southern Guangxi Province. Within the province, rapid growth in the silk processing industry in recent years has had significant impacts on farms for rearing silkworms and mulberry trees.

Income from crop production generally dominates household income. However, land is not evenly distributed and farms with less land focus more on livestock production. The last land redistribution within the province occurred in the 1980s, although some villages have readjusted land distribution among farms every 5 years since then. Land-holding size is generally small. It

[21 &22] Based on the fifth national census data in 2000, National Bureau of Statistics of China.

is common to have a half mu per person[23]. In general, regions in the north and east part of the county have less land than in the south and west. In the south, the predominant crop is sugarcane. Cassava, corn, rubber trees and fruit trees are also popular. Soybeans are intercropped with other crops or vegetables. The main function of growing soybeans is to add nutrients to the soil in general. In the northern regions, soybean production scale is larger. The economic situation is better in the north than in the south; there are better climatic conditions in the north which makes it more suitable for farming than the south.

Off-farm job opportunities are clustered in Guangdong Province. Local farm laborers also migrate to urban locations within Guangxi Province, such as the capital Nanning City, where small businesses are rapidly emerging. Main employment opportunities are trading agricultural products, and engaging in the garment, service, construction and transportation industries. Since 2000, real prices for agricultural products have increased on average, providing more incentives for agricultural production. However, off-farm income is the most important income source, especially for farm households who possess less land.

4.3 Data Characteristics and Descriptive Statistics

4.3.1 Demographic Characteristics

The household questionnaires for the socioeconomic studies provide an understanding of farm production, and consumption patterns, and needs in the study sites. Each household survey is comprised of eight modules, which offer an integrated evaluation of household standard-of-living. The eight modules are (i) household profile, (ii) source of household income and time allocation, (iii) preferences for on-farm versus off-farm employment, (iv) food security, (v) soybean production, consumption and barriers to adoption, (vi) current household economic

[23] 1 acre = 6.07 mu

situation, changes, and expectations (vii) household assets, and (viii) household decision-making. Table 4.1 highlights selected demographic characteristics from the household surveys. The total sample size is 247 households. For those analyses restricted to 'coupled households' only, the sample size is reduced to 222 households which include primary couples between 25 and 70 years of age for husband and between 23 and 65 years of age for wife. On average, across all five counties, the primary couples' ages are between 45 and 50, with wives' schooling 2-7 years and husbands' schooling 5-9 years.

4.3.2 Labor Force Characteristics

There have been growing concerns of the impacts of migration behavior on the population structure in China's rural regions. According to United Nations' population projections, China is currently and will continue to experience a dramatic increase in its elderly population. By 2050, China will have about 470 million people above age 60, which accounts for 31 percent of the total Chinese population**.** This percentage is almost double the average of other less developed regions considering the population aged at 60 and above **(**United Nation Population Fund (UNFPA) Report, 2007**).**

Poston and Duan (2000) suggest that by 2050, China will have 14 percent of the world's population but will have 21 percent of the world's elderly. Bartlett and Phillips (1997) focus on the family structure of the aging problem in rural China and argue that the tradition of married daughters living with the husband's family jeopardizes the family care of the rural elderly who only have daughters. They suggest that the lack of comprehensive pension and assistance schemes makes the situation particularly problematic in aging rural China.

Table 4.1 Demographic characteristics of south China survey sample, 2006.

	Guangdong	Hunan	Guangxi		
Demographic characteristics	**Yingde (n = 88)**	**Xintian (n = 40)**	**Longan (n = 28)**	**Laibin (n = 33)**	**Lingchuan (n = 58)**
Average household size	5.24	5.42	4.83	5.48	4.47
Average age of adult male respondent	49.00	49.13	46.33	49.85	48.40
Average schooling of male (years)	5.59	8.97	6.83	6.00	6.74
Average age of adult female respondent	46.82	46.23	44.94	48.04	46.70
Average schooling of female (years)	2.80	6.48	4.72	3.26	5.88
Percentages of households with number of[24]:					
Males aged 18 & above =1	39	37	33	39	27
Males aged 18 & above =2	39	22	35	32	39
Males aged 18 & above =3	22	26	26	23	27
Males aged 18 & above =4	0	7	5	6	6
Males aged 18 & above =5	0	4	2	0	0
Males aged 18 & above =6	0	4	0	0	0
Females aged 18 & above =1	33	33	37	32	37
Females aged 18 & above =2	17	37	44	35	41
Females aged 18 & above =3	39	22	16	19	8
Females aged 18 & above =4	11	7	0	6	10
Females aged 18 & above =5	0	0	2	3	2
Females aged 18 & above =6	0	0	0	3	0
Females aged 18 & above =7	0	0	0	0	2
Males aged 15 to 17[25] =0	94	74	91	84	86
Males aged 15 to 17 =1	5	26	9	13	12
Males aged 15 to 17 =2	0	0	0	3	2
Females aged 15 to 17 =0	94	63	98	90	82
Females aged 15 to 17 =1	6	26	2	6	18
Females aged 15 to 17 =2	0	11	0	3	0
Males aged 12 to 14 =0	78	93	95	94	94
Males aged 12 to 14 =1	22	7	5	6	6
Females aged 12 to 14 =0	100	93	98	94	96
Females aged 12 to 14 =1	0	7	2	3	4
Females aged 12 to 14 =2	0	0	0	3	0
Children aged 6 to 11 =0	72	81	88	81	78
Children aged 6 to 11 =1	22	15	12	13	16
Children aged 6 to 11 =2	6	4	0	6	6
Children aged 5 & below =0	94	93	93	71	82
Children aged 5 & below =1	6	7	5	19	12
Children aged 5 & below =2	0	0	2	10	4
Children aged 5 & below =3	0	0	0	0	2
Percent of households with elderly parent(s) present	12	13	28	11	16

[24] Each age categories by gender should sum up to 100%. In a few occasions, rounding to the nearest integer number may lead to a sum of 99%.
[25] Endpoint years inclusive.

Zeng and Vauple (1989) argue that because migrants tend to be young, rural China is facing a more severe aging population problem than urban regions. The trade-offs between migration and early child birth or low fertility rate lead to slow population growth in rural regions, which in turn contributes to the proportion of elderly population. They suggest that the policymakers should consider the steadily declining rate of agricultural productivity due to the aging labor force in rural areas. At the same time, as the younger population pours into urban areas, it may help urban economic growth, which contributes to a stronger urban growth rate and attracts more rural younger labor to migrate. Zhao (1999) uses a pooled household dataset for 1994 and 1995 to compare the characteristics of migrants and non-migrants and suggests that age negatively affects the probability of migration. The results reveal that the average age of non-migrants is 36.4 years, which is 10 years older than migrants at 26.8 years.

The sample data collected in this study confirms China's aging population structure, with the heavy out-migration trend contributing to the aging population structure observed in the villages. According to national census data, at the end of 2006, the rural labor force resource was 5,310 million people. Among these, 1,318 million individuals were migrant laborers who worked in off-farm jobs; 36.5 percent of those individuals were 21 and 30 years old and 29.5 percent were31 to 40 years old. It is worth noting that by the end of 2006, 1,327 million elderly lived in China's rural regions. Only 6.7 million of this population engaged in off-farm work in urban regions, which is only 5 percent of all individuals who worked for urban employment. Thus, the dominant trend of rural to urban migration speeds up the formation of an elderly society in rural regions of China. At the same time, as the world's most populated county, it is crucial for China to secure the food supply, which is closely linked to the issue of rural population and rural-urban migration behavior.

Table 4.2 includes labor force characteristics from the south China sample data. Male and female labor supply activities are separated into categories of farm production, off-farm production, off-farm self-employment, and home production [26]. Farm production is subcategorized into working on own farm soybean production, working on own farm other crop production, working on other's farm soybean production, and working on other's farm other crop production. Work participation behaviors are summarized in percentage and labor time allocation in each work category, measured in average yearly hours (restricted to those who work in that activity). 'Other' household adult male and female members' farm production participation behavior also is included in the table. A further comparison of the average yearly hours spent on crop production on own farm between adult male/female (primary couple) and all household members indicates that farm production mainly relies on the primary adult male and female. The average crop production of the adult male ranged (approximately) between 1000 to 2200 yearly hours across the five study sites, while the average crop production of all adult males ranged (approximately) between 1100 to 2500 annual hours. The average crop production of the adult females ranged (approximately) between 1000 to 2300 annual hours, while the average crop production of all adult females in the households ranged (approximately) between 1100 to 2400 hours annually.

The household profile module contains information about all household members' time allocation. Figure 4.2 shows the age distribution of labor in farm production. The major farm production labor force is aged between 45 and 54 years old. It is worth noting that approximately 60% of the 35 to 44 year old age group sample population engaged in some sort of farming activities. The farming engagement percentage is about the same for the 65 to 74 year old age group, while the percentage is much lower (26%) for the 25 to 34 year old age group.

[26] Home production includes common household work, such as cooking, cleaning, taking care of elderly and young.

Table 4.2 Labor force characteristics of south China survey sample, 2006.

	Guangdong	Hunan	Guangxi		
Labor force characteristics	Yingde (n = 88)	Xintian (n = 40)	Longan (n = 28)	Laibin (n = 33)	Lingchuan (n = 58)
Respondent labor participation [a]:					
Adult male respondents in own farm soybean production (%)	90	100	89	93	72
Adult male respondents in own farm other crop production (%)	82	100	78	100	79
Adult male respondents working on other farm's/farms' soybean production (%)	2	13	6	4	2
Adult male respondents working on other farm's/farms' other crop production (%)	0	23	6	15	2
Adult female respondents in soybean production (%)	92	100	94	93	98
Adult female respondents in other crops production (%)	88	100	83	96	88
Adult female respondents working on other farm's/farms' soybean production (%)	2	10	11	4	2
Adult female respondents working on other farm's/farms' other crop production (%)	o	19	11	22	14
Adult male respondents [b]:					
Average crop production annual hours	1112	999	1359	2220	935
Average nonfarm annual hours	2464	2400	192	240	842
Average nonfarm self-employment annual hours	896	630	0	0	1470
Average home production annual hours	346	165	479	375	413
Adult female respondents [b]:					
Average crop production annual hours	1302	1053	1752	2319	1283
Average nonfarm annual hours	320	672	192	320	803
Average nonfarm self-employment annual hours	1096	1827	0	0	1220
Average home production annual hours	1272	1299	1008	976	1031
Average annual total work hours – male respondents [c]	2055	1609	2163	2785	1873
Average annual total work hours – female respondents [c]	2532	2644	2704	3264	2374
Other household member labor behaviors:					
Percentage of households with number of:					
Other adult males working on farm =0	74.51	83.87	72.22	81.48	79.07
Other adult males working on farm =1	23.53	12.90	27.78	14.81	16.28
Number of other adult males working on farm =2	1.96	3.23	0.00	0.00	4.65
Number of other adult males working on farm =3	0.00	0.00	0.00	3.70	0.00
Number of other adult females working on farm =0	84.31	93.55	88.89	92.59	88.37
Number of other adult females working on farm =1	11.76	6.45	5.56	7.41	11.63
Number of other adult females working on farm =2	3.92	0.00	5.56	0.00	0.00
Average crop production annual hours:					
All adult males in household	1366	1132	1455	2539	1153
All adult females in household	1472	1130	1894	2395	1376

Note: a. Respondents only
b. Only for those participating
c. All

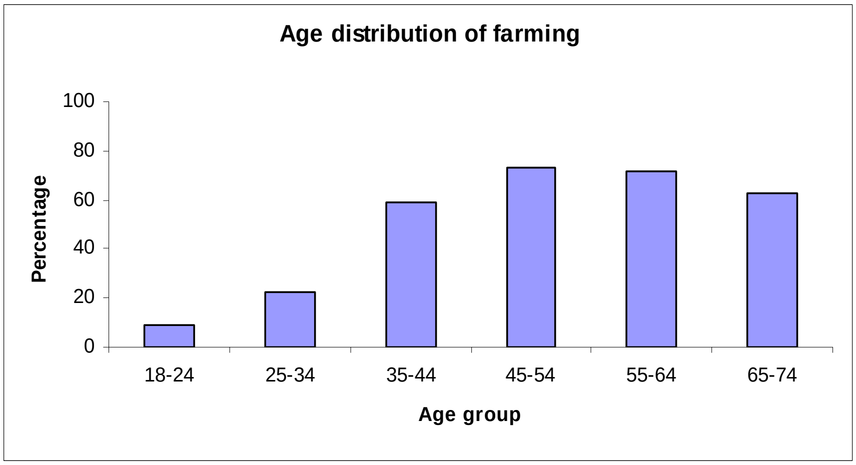


Figure 4.2 Farm production participation rates among age groups, south China survey sample, 2006

To examine gender differences in work participation in the 2006 data, figures 4.3a and 4.3b present gender differences in terms of work participation behaviors with age. Comparisons between the two figures show that boys start working on-farm earlier than girls. At age 13 to 17 years old, 50% of boys spent some time working on-farm and another 50% of boys work on off-farm jobs, while 90% of girls help out on the farms and 10% of girls work off-farm. Off-farm work participation is highest at age 18 to 24 years old for both adult males and females, with slightly higher work participation percentages in females (90%) than for males. For the same age group, 12% of males work exclusively on-farm, slightly higher than the 6% for females.

The trends show that the off-farm work participation percentage decreases sharply for females aged between 30 to 40 years old. For females 35 to 44 years old, the participation percentage for working *exclusively off-farm* reduces to 7% and working *exclusively on-farm* increases to 63%. At ages 45 to 54 years old, only 5% of females still work exclusively off-farm, and 80% of females work in on-farm production only. The participation percentage for males working off-farm exclusively gradually decreases after 25 years of age. At ages between 45 and 54 years old, work participation percentages for working exclusively on-farm, both on-farm and off-farm, and exclusively off-farm are 60%, 30%, and 10%, respectively. The life-cycle patterns for males working exclusively off-farm is approximately 10 years longer than for females; the percentage of exclusive on-farm production exceeds exclusive off-farm production for males at around age 44, compared to females at an age around 35.

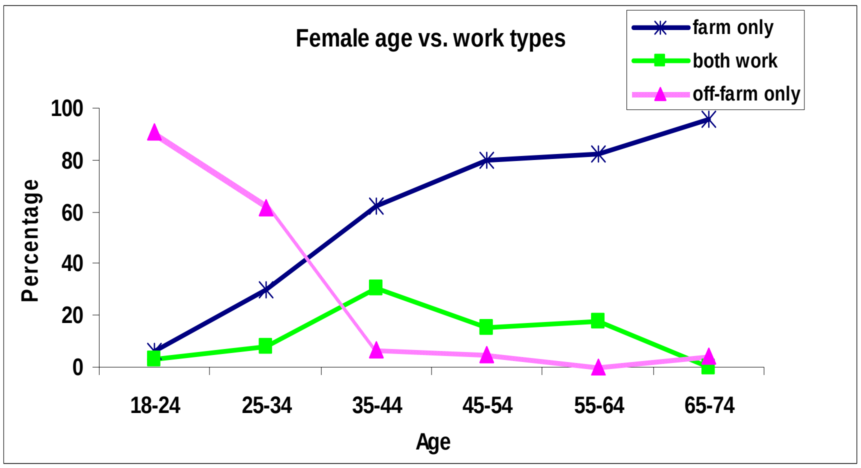


Figure 4.3a Farm vs. nonfarm work participation percentages among females by age groups

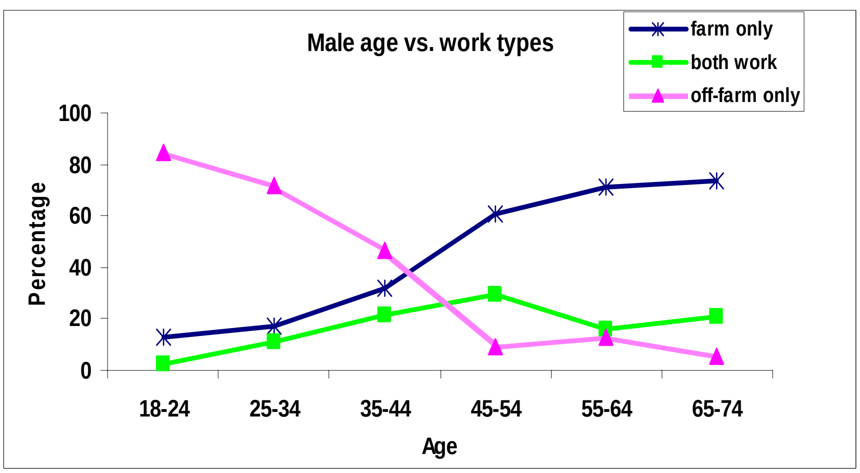


Figure 4.3b Farm vs. nonfarm work participation percentages among males by age groups

4.3.3 Crop Income, Land Constraint and Socio-economic Characteristics

As shown in table 4.3, two variables measuring the distance to farm market and town market are expected to influence farm production. The distance to the farm market indicates spatial distance of one village to the nearest local farm market. The distance to town market is an indication to the remoteness of a village to more urban locations (i.e., towns, etc.). The average distance to farm market is 3.71 km, and to town market 8.80 km.

On average, total land owned by households, including arable land and housing site, is 7.92 mu, and the average total arable land is 6.98 mu[27]. The small land holdings per household have been shown by previous studies to strongly affect farm production and risk-taking ability in new technology adoption (Li, Rozelle and Brandt, 1998; Tan, Heerink and Qu, 2006).

Table 4.3 Additional selected characteristics, south China survey sample, 2006.

Additional characteristics	**Guangdong**	**Hunan**	**Guangxi**		
	Yingde (n = 88)	**Xintian (n = 40)**	**Longan (n = 28)**	**Laibin (n = 33)**	**Lingchuan (n = 58)**
Average farm land size and annual crop income					
Average arable land size (mu)	6.04	7.67	3.41	9.05	5.75
Average crop income in 2005 (yuan)	2663	5007	920	2242	1293
Selected development indicators					
Average distance to town market (km)	4.57	10.67	10.77	10.56	2.56
Average distance to farm market (km)	3.38	1.85	8.07	3.91	1.13
Percentage of households with					
Well water or piped water	100	97	58	96	98
Home sewage disposal system	32	0	0	46	27
Using fuels other than wood for cooking	53	97	46	36	57
Continuous electricity supply to house	83	100	92	89	95

4.4 Soybean Production, Consumption and Marketing

China is the world's top soybean importing country and the world's leading oil processing country, based on Food and Agriculture Organization of the United Nations (FAO) data. FAO data show that from 1992 to 2008, the real soybean producer price in China was, however, the highest among other leading soybean-producing countries (Argentina, Brazil, and the United States) (see figure 4.4). Domestically, the soybean producer price is generally the

[27] 1 acre = 6.07 mu

highest among five major crops (soybeans, maize, rice, sugar cane, and sweet potatoes), on a US dollar per ton basis (see figure 4.5).

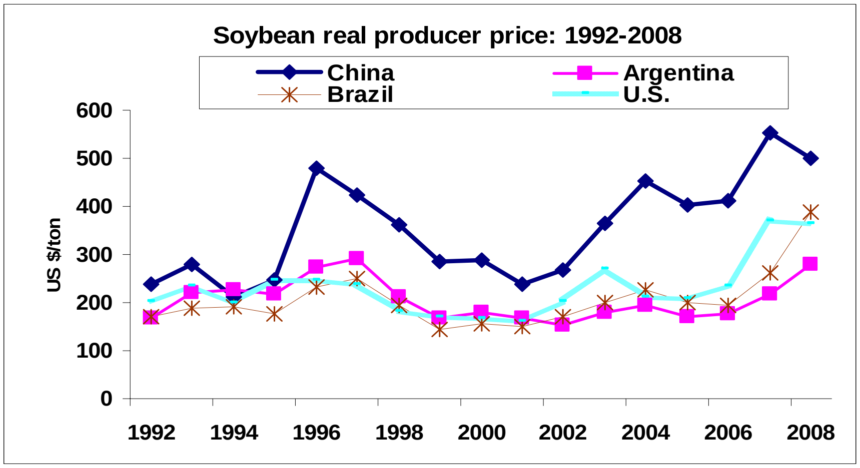


Figure 4.4 Four major soybean producing countries soybean producer prices: 1992 -2008[28]
(Source: FAO data)

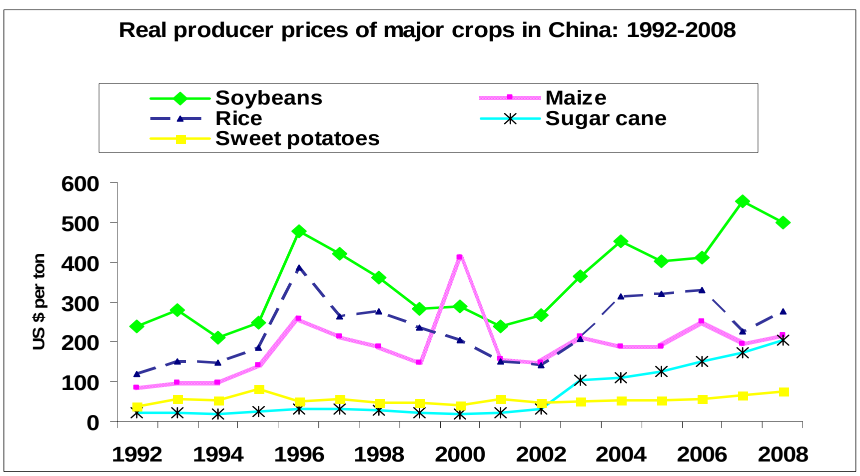


Figure 4.5 Producer prices for five major crops in China: 1992-2008[29]
(Source: FAO data)

Given these conditions, the majority (72%) of farmers answered 'no problem' with respect to any problems encountered with respect to selling soybeans. Interestingly, 23% of farmers answered that it is hard to negotiate a better price with brokers. And 6% of farmers

[28] Food and Agriculture Organization of the United Nations (FAO) data. Agricultural price indices: 2005=100
[29] Food and Agriculture Organization of the United Nations (FAO) data, Agricultural price indices: 2005=100

believe that keeping soybeans fresh and away from pest damage is a main problem during storage. Only one farm household answered yes to having trouble selling soybeans. Figure 4.6 shows the marketing channels for soybean output when the survey was conducted. A reported 55% of surveyed farm households sell their soybeans to brokers who come to the villages and buy soybeans at the farm door.

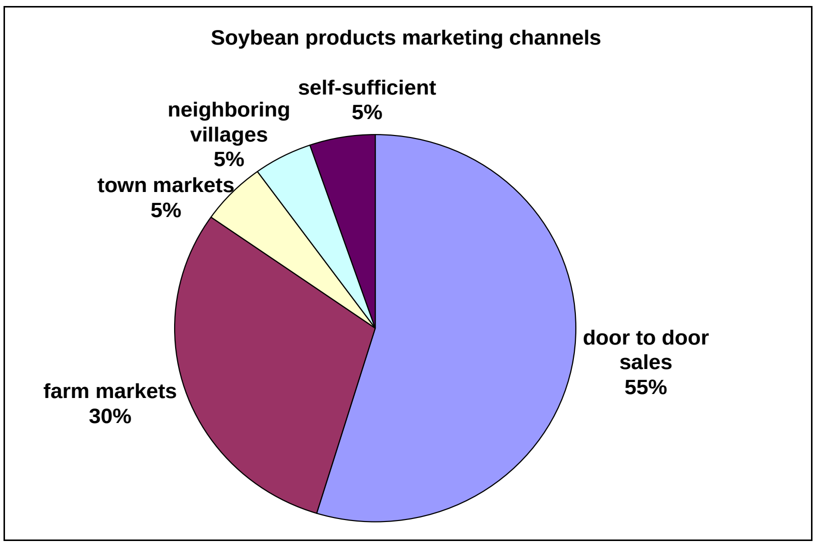


Figure 4.6 Soybean marketing channels, female response, 2006

Figure 4.7 presents respondents' expectations of their adoption of P-efficient soybean cultivars, changes in land allocation corresponding to the new soybean cultivar adoption, additional yield distribution, and current soybean output consumption patterns. The large majority of survey respondents – the farmers – showed significant interest in the new P-efficient cultivars. Almost all responded that they anticipate adopting the cultivars. Less than 13% of females and less than 5% of males responded that they were unsure or that they would not adopt on their farms. Further, almost 65% of females and 80% of males responded that they would *increase* the amount of farm land allocated to soybean production, if higher yielding low-P cultivars were available. The higher yields were viewed very positively by farmers, with females slightly more conservative than males in terms of their expectations regarding new P-efficient soybean cultivars adoption and land allocation decisions (see fig. 4.7 comparing male and female responses).

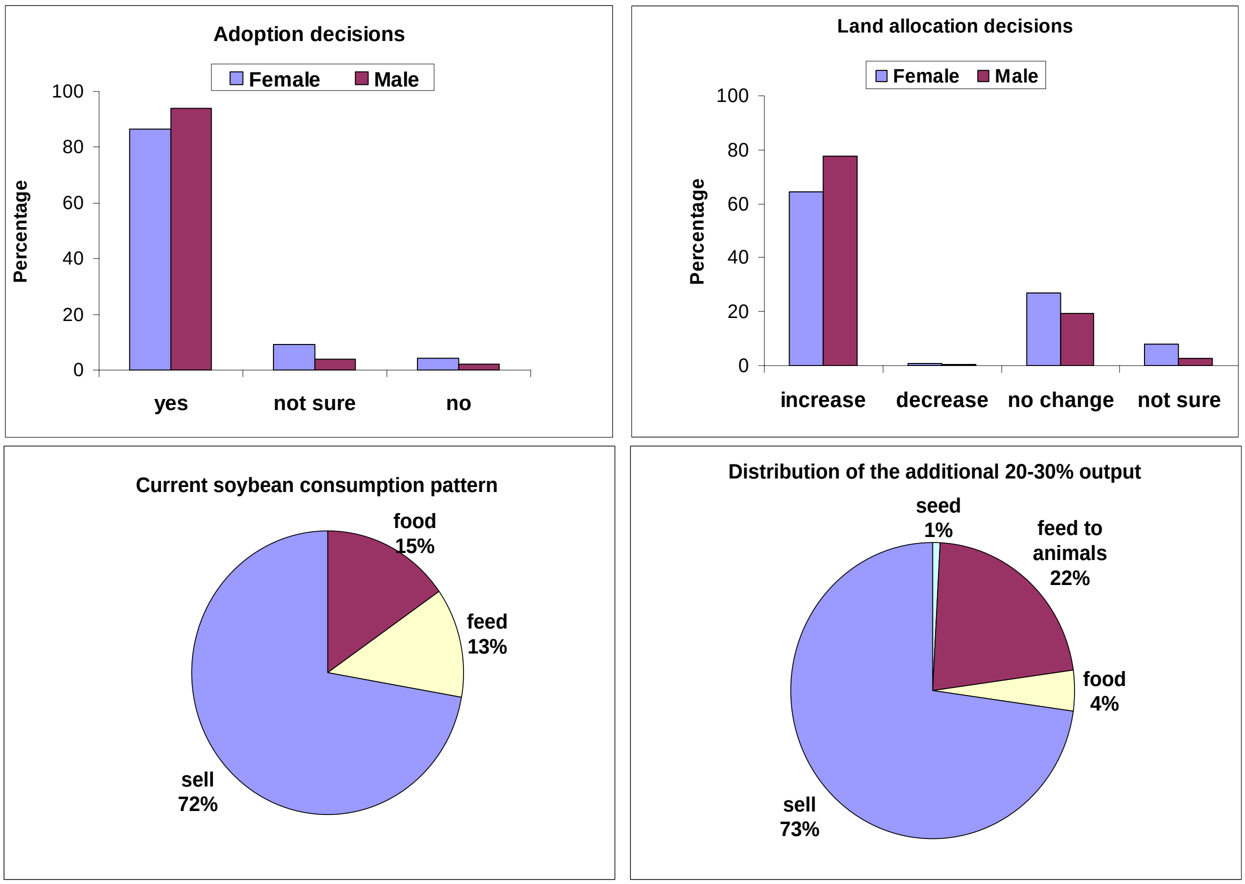


Figure 4.7 Responses related to adoption decisions of new P-efficient soybean cultivars

Farmers reported that, at the time of the survey, an average 15% of soybeans produced are consumed by their households, with an additional 13% being used on-farm for animal feed. The remainder (72%) is sold (figure 4.7). When asked how they anticipate the higher yields will be utilized, farmers responded that roughly the same percentage (73%) of the additional soybeans would be diverted for sale to markets, but with a higher proportion of the additional amount being allocated to own farm animal feed on their own farms than previously (refer to figure 4.7). The results reflect the belief that additional output can be sold, and that while there could be small increases in home consumption of soybeans, the more likely scenario would be using additional soybean output to feed to livestock.

Finally, farmers were asked if the new cultivars could be expected to result in a better standard-of-living in their villages and for their households. Responses show that the realization of a higher farm household standard-of-living from adopting new low-P soybean cultivars is expected to be influenced by 1) labor time allocation influenced by patterns of out-migration as well as willingness to produce soybeans and soybean products, and 2) functioning of land-leasing markets. The existence, functioning and prices received in markets for soybean products, including soybeans used for bio-energy production and livestock feed, are expected to impact household outcomes, particularly if producing households are (already) self-sufficient in soybeans for own consumption. Further, the dramatic trend of rural-to-urban labor migration now observed in south China implies large-scale shifts of labor across the entire region into off-farm employment.

Chapter 5

EMPIRICAL MODEL AND ESTIMATION RESULTS

5.1 Labor Time Allocation and Household Sharing Rule

5.1.1 Estimation Strategy

Agricultural production still remains a major income source for farm households in rural south China. The mixed labor supply behavior for farm production, wage market employment, nonfarm self-employment and home production needs to be addressed. Although we focus on labor time allocation and the sharing rule for a simplified household with two members (husband and wife) only, the labor time allocation by other household members is important to construct the actual production function and provide instruments for the production function and shadow wage estimations. The empirical estimation will be conducted in three steps: In the first step, the farm production function for households in which at least one spouse is engaged in farm production will be estimated. Then, the farm shadow wage based on time spent in farm production only will be found. Since the output of home production is not observable, the shadow farm wage is used in place of the marginal product of labor in home production, following Jacoby (1993). For individuals working exclusively in home production, the average village-level farm shadow wage by gender is considered to be the opportunity cost of home production. According to Jacoby (1993), farm profit can be calculated and is used together with remittances sent home by other household members or relatives to determine 'nonlabor income'.

In the second step, individual's total labor supply function is estimated. The endogeneity of shadow wage is addressed (see section 5.1.3.2). Since nonlabor income is derived after proper deduction of labor income (as in Jacoby, 1993), it is also expected to correlate with the error term. Instrumental variables are used to correct such correlation and obtain unbiased parameters, which are important in construction of the partial derivatives of the sharing rule.

In the third step, the sharing rule is presented. The impact of increasing shadow wage for both spouses on the sharing rule and transferring of nonlabor income between household members is analyzed to illustrate the intrahousehold welfare distribution. The distribution factor of migrants' sex ratio at the origin county is also expected to affect the sharing rule results (see section 5.1.3.1 for discussion of the distribution factors).

In the final step, by taking the advantage of our unique dataset, household decision-making structure is revealed, which covers the perspectives of consumption, production, marketing and innovation. We investigate the linkage between intrahousehold budget sharing and individual member's engagement in household decision-making. The results are powerful in understanding farm households' labor supply behaviors. It is especially helpful for explaining why some households more readily adopt new agricultural technologies than others from the intrahousehold resource allocation point of view.

5.1.2 Shadow Wage and Nonlabor Income

We start off in farm shadow wage estimation. The labor inputs are divided into adult males and adult females in a household. The size of farm land is the fixed input. Output value is given by the total crop income in the previous year, with production costs (e.g., expenses for chemical inputs and seeds) deducted from the reported value. Labor time spent on farm production corresponds to crop production only. The production function is specified as a Cobb-Douglas function:

$$Q = \beta_0 L_m^{\beta_m} L_f^{\beta_f} F^{\beta_F}$$

where L_m, L_f and F denote the sum of on-farm working hours by household adult males, the sum of on-farm working hours by household adult females, and farm land, respectively. By taking the natural logarithm on both sides of the equation, the linearized production function is:

$$\ln(Q) = \beta_0 + \beta_m \ln(L_m) + \beta_f \ln(L_f) + \beta_F \ln(F) + \beta_z z + \varepsilon$$

where ε is the disturbance term. The concern for endogeneity problem arises when ε contains any "fixed" effects, for example, unobserved individual characteristics or farming skills, which are likely to influence output and thus correlate with the disturbance term, but fail to be captured by the production function (Jacoby, 1993). In other words, some variables that have direct impacts on production are possibly omitted in the dataset. As the endogeneity is caused by omitted variables, the OLS coefficients are biased. We follow the common strategy used in cross-sectional data of selecting instrumental variables (IV) that are correlated with the input variables but not with the disturbance term, to correct for the endogeneity problem. The specific IVs are described in section 5.3.1. Next, the shadow wages for males and females in a household are estimated by $MPL_i = p\,{}^{\partial Q}\!/_{\partial L_i} = \hat{\beta}_i \hat{y} / L_i$ [30] for $i = m, f$, where $\hat{\beta}_i$ are the coefficients on $\ln(L_i)$, and $\hat{y}$ is the fitted value of output.

As shown in [P1.4a] and [P1.4b], the farm shadow wage deviates from the off-farm market wage only if an individual's labor allocation behavior is affected by labor market restrictions. Therefore, rather than assuming that the entire sample is subject to the imperfect labor market constraint by equalizing the marginal product of labor with the farm shadow wage, we look into different labor supply scenarios for individual cases. As the survey asked questions

---

[30] MPL_i for individual *i* refers to the marginal (value) product of labor. See page 50 in Jacoby's dissertation: "A shadow wage approach to estimate a labor supply model for peasant households: An application to the Peruvian Sierra".

regarding starting and ending months for all work categories (on-farm, off-farm, off-farm self-employment, and home production), we are able to identify a group of people that work full-time for market wage. Then self-reported wage is used in the labor supply estimation. The self-reported off-farm self-employment income is converted into an hourly wage for those working full-time on own nonfarm business. The only remaining issue is the group of people working part-time for wage and part-time on farm. Our solution is to test whether the discrepancy between the farm shadow wage and off-farm wage is statistically significant. According to Jacoby (1993) and Skoufias (1994), the true marginal product of labor is consistent with the shadow wage. The regression is expressed as: $MPL_i = a + bw_i + e_i$ for $i = m, f$. The null hypothesis assumes $a = 0$ and $b = 1$, for the equalization of MPL and market wage. Once the shadow wage is obtained, the nonlabor income (y) is calculated according to [P1.4c].

5.1.3 Recovering the Intrahousehold Sharing Rule

5.1.3.1 *Functional Form of Labor Supply*

The next step is to estimate the total labor supply function. Following Chiappori, Fortin and Lacroix (2002), a functional form is specified as:

$$\ln(h_f) = f_0 + f_1 \log w_f^* + f_2 \log w_m^* + f_3 y^* + f_4 \ln w_f^* \ln w_m^* + f_5 k + f_6 z + v_f$$
$$\ln(h_m) = m_0 + m_1 \log w_f^* + m_2 \log w_m^* + m_3 y^* + m_4 \ln w_f^* \ln w_m^* + m_5 k + m_6 z + v_m$$

where shadow wage (w_f^*, w_m^*) is the same as the market wage if an individual works full-time off-farm. The inclusion of the distribution factors (*k*) is an important contribution by Chiappori, Fortin and Lacroix (2002). In their study, the impacts of the marriage market and divorce legislation on intra-household labor supply behavior are measured through distribution factors, which affect the household members' welfare weight, but do not alter individual preferences or the household members' joint consumption set. They use state-level sex ratios by race and a divorce law indicator combining four distinctive features of divorce laws for the proxies for marriage market and divorce legislation, respectively. Their study results show the significant impact of distribution factors on labor supply behavior and more importantly, by introducing distribution factors into the collective model, the identification of the structure parameters is greatly simplified (Chiappori, Fortin and Lacroix, 2002). The identification of intrahousehold transfer and the sharing rule can be derived from the sole observation of labor supply (Chiappori, Fortin and Lacroix, 2002). Their study extends Chiappori (1992), who develops a general framework for the collective model of household labor supply. Rapoport et al. (2007) extend the Chiappori, Fortin and Lacroix (2002) collective model by including home production using French time-use survey. They use regional sex ratio by age as the distribution factors. In our study, the impact of rural labor out-migration on intra-household labor time allocation decisions naturally involves out-migrants' sex ratio. So we employ the migrants' sex ratio by age categories at the origin county as the distribution factor included in the labor supply functions. The hypothesis is that when males are more engaged in migration, there is a relative scarcity of males in the villages and this may positively affect the intrahousehold welfare distribution towards females.

5.1.3.2 *Endogenously Determined Shadow Wage*

In the labor supply functions, the market wage is generally assumed exogenous to individuals. The concept is analogous to consumer theory where consumers are price takers. But the issue gets more complicated in the absence of a wage for farm self-employment. The opportunity cost of time or shadow wage is determined within a household by a simultaneous structure of both labor demand and supply, rather than from market forces (Lopez 1986; Jacoby 1993; Skoufias 1994). We adopt a general method developed by Jacoby for estimating structural time-allocation models for agricultural households. The limitation of cross-sectional data requires using instrumental variables, which are regressed on the endogenous variables (shadow wages and nonlabor income) in estimating both labor supply functions. Male and female's labor supply functions are estimated here separately (not aggregated), since we do not assume a perfect substitution between male and female labor.

5.1.4 Sharing Rule Specification

Labor time allocation is used as the assignable good since private consumption data were not possible to obtain in our study. The purpose of identifying all parameters in the above labor supply functions is to reveal the sharing rule through the process of intrahousehold negotiation in labor time allocation. Based on the efficiency assumption, one member's one dollar extra income has an effect on the other member's labor supply behavior, corresponding to the changes in the sharing rule between both members. Again the sharing rule is defined as $\phi(w_1^*, w_2^*, y^*, k, z)$, such that $\phi_f = \phi$ and $\phi_m = y^* - \phi$, where ϕ_f denotes female's share of nonlabor (pooled) income and ϕ_m denotes male's share of nonlabor (pooled) income. To be consistent with Chiappori, Fortin and Lacroix (2002), the marginal rate of substitution between wage and nonlabor income is through the sharing rule effect only, and:

$$A = \frac{h_{w_m}^f}{h_y^f} = \frac{f_2 + f_4 \ln w_f^*}{w_m f_3} = \frac{\phi_{w_m^*}}{\phi_{y^*}}$$

$$B = \frac{h_{w_f}^m}{h_y^m} = \frac{m_1 + m_4 \ln w_m^*}{w_f m_3} = -\frac{\phi_{w_f^*}}{1 - \phi_{y^*}}$$

Similarly, the marginal rate of substitution between the distribution factor and nonlabor income is through the sharing rule effect only (Chiappori, Fortin and Lacroix, 2002). Then define:

$$C = \frac{h_k^f}{h_y^f} = \frac{f_5}{f_3} = \frac{\phi_k}{\phi_{y^*}}$$

$$D = \frac{h_k^m}{h_y^m} = \frac{m_5}{m_3} = -\frac{\phi_k}{1-\phi_{y^*}}$$

with $\phi_{y^*}(1-\phi_{y^*}) \neq 0$.

The partial derivatives of the sharing rule with respect to shadow wages, nonlabor income, and the distribution factor are:

$$\phi_{y^*} = \frac{D}{D-C} = \frac{f_3 m_5}{\Delta}$$

$$\phi_k = \frac{CD}{D-C} = \frac{f_5 m_5}{\Delta}$$

$$\phi_{w_f^*} = \frac{BC}{D-C} = \frac{f_5(m_1 + m_4 \ln w_m^*)}{w_f^* \Delta}$$

$$\phi_{w_m^*} = \frac{AD}{D-C} = \frac{m_5(f_2 + f_4 \ln w_f^*)}{w_m^* \Delta}$$

with $\Delta = f_3 m_5 - m_3 f_5$

Then the integrated sharing rule function is derived as:

$$\phi = \frac{1}{\Delta}(m_1 f_5 \ln w_f^* + f_2 m_5 \ln w_m^* + f_3 m_5 y^* + f_5 m_5 k + (f_4 m_5 + m_4 f_5) \ln w_f^* \ln w_m^*)$$

where the cross term of $\ln w_f^*$ and $\ln w_m^*$ has the same effects on both members. The sharing rule can be recovered up to an additive constant (Chiappori, 1997; Chiappori, Fortin and Lacroix, 2002).

5.2 Intra-Household Decision-Making Structure

Our focus on intrahousehold decisions is still between two household members, but involves joint decision-making structures potentially involving other adults in a household. We use the standard multinomial logit regression to determine the impact of factors on who within the household is engaged in decision-making. It is assumed that all individuals engaged in decision-making have some voice in the process.

The multinomial logit regression extends the binary logit regression model, with one category of dependent variable ($y_i = 0$) chosen as the base or comparison category, which is omitted from the analysis (Hausman, 1984). The other categories compare with the base category to determine the relative probability that a particular outcome category $(y_i = j, \; j \neq 0)$ happens. Based on our survey results, for each decision-making question, the given options of who makes the decision include six categories: husband makes a decision alone ($j = 0$), wife makes a decision alone ($j = 1$), husband and wife make a joint decision ($j = 2$), adult males make a joint decision ($j = 3$), adult females make a joint decision ($j = 4$), and all adults make a joint decision ($j = 5$). We choose husband makes a decision alone as a base category for the multinomial logit regression. As a result, the remaining five decision-making categories reflect a household decision-making structure that deviates from a husband dominant decision-making pattern. A vector of explanatory variables (X_i) is estimated by the maximum likelihood method to capture the significance and magnitude of their impacts on household *i*'s decision-making structure. The probability for household *i*'s decision-making category is specified as:

$$Pr(y_i = j) = \frac{e^{\beta_j X_i}}{\sum_{j=0}^{6} e^{\beta_j X_i}}$$

where *j=0,1…6*. For the base category, we impose the normalization $\beta_0 = 0$, then $e^{\beta_j X_i}$ =1. The above probability can be rewritten:

$$Pr(y_i = 0) = \frac{1}{1 + \sum_{j=1}^{6} e^{\beta_j X_i}}$$

and $$Pr(y_i = j) = \frac{e^{\beta_j X_i}}{1 + \sum_{j=1}^{6} e^{\beta_j X_i}} \qquad \text{for } j = 1\ldots6$$

The unknown parameters β_j are estimated by maximum likelihood.

5.3 Estimation Results

5.3.1 The Production Function and Shadow Wage Estimation

For the 2006 survey, we interviewed people living in rural villages in a door-to-door interview format. In total 247 households were interviewed; the quantitative surveys covered detailed weekly time use data for each household member, household income components, preferences for on-farm versus off-farm employment, market wages if works off-farm, household decision-making from the perspectives of both husband and wife, and household economic situation. Since we focus on two-member household behaviors, the household head and the spouse are selected to be the primary couple. The sample size declines to 222 households.

Summary statistics for production function estimation are presented in table 5.1. The endogenous variables in the production function include labor time in crop production and land input for crop production. Exogenous variables include household head's age, age squared (a proxy for farming experience) and schooling. Survey questions specifically asked who the household head is for each interview household.

Table 5.1 Descriptive statistics for variables and instrumental variables used in production function estimation

	Mean	Std. Dev.	Min	Max
Dependent variable:				
All crop production income (yuan: 1US$ = 7.99 yuan in 2006)	2615.925	3186.699	80	22300
Endogenous variables:				
Adult female crop production yearly hours	1576.818	1177.859	72	6688
Adult male crop production yearly hours	1465.053	1180.136	16	6160
Land (mu: 1 acre=6.072mu)	6.255	3.139	0	22
Exogenous variables:				
Household head age	47.480	9.623	25	70
Household head schooling (years)	6.844	3.270	0	16
Distance to farm market (km)	3.126	2.569	1	11.134
Distance to town market (km)	6.550	3.628	2.387	13.599
Instrumental variables:				
Number of males age ≥ 18	2.036	1.013	1	6
Number of females age ≥ 18	1.978	1.046	1	7
Number of males age between 15 and 17	0.169	0.410	0	2
Number of females age between 15 and 17	0.160	0.413	0	2
Number of males age between 12 and 14	0.102	0.332	0	2
Number of females age between 12 and 14	0.711	0.274	0	2
Number of children age between 6 and 11	0.258	0.555	0	3
Number of children age ≤ 5	0.191	0.512	0	3
Live with elderly parents (1 = yes, 0 = no)	0.151	0.359	0	1
Water system (0 if depends on rain water or from river, 1 otherwise)	0.942	0.234	0	1
Sewage disposal (0 if none, 1 otherwise)	0.240	0.428	0	1
Cooking fuel (0 if use wood only, 1 otherwise)	0.587	0.494	0	1
Electricity (0 if no electricity some days during a week, 1 otherwise)	0.907	0.292	0	1

Distance to farm market and to town market are also included as exogenous variables at the village level. The set of instrumental variables used to correct the endogeneity problem (due to “fixed” effect in farm production, see previous discussion in section 5.1.2) are chosen similarly to Jacoby’s study. We include the demographics of a household, village facilities (water system and electricity availability), and household amenities (sewage disposal and cooking fuel). Members in each household are divided into 8 categories by age and gender, including children from 6 and 11 years old inclusive, and children below 5 years old.

Table 5.2 presents the coefficients estimated by the C-D production function with standard errors in parentheses. The coefficient of adult female labor is slightly higher than the coefficient of adult male labor, since females were found to spend slightly more time working on crop production than males. But on average, the MPL of males still exceeds the MPL of females. The household head’s years of schooling has a positive effect on production; every extra year of education increases crop production income by nearly 7%.

The two distance variables (farm market and town market) show significant effects on farm production income. Measured by the distance to the nearest farm market, the farther away a household is from a farm market, the lower the crop production income. Considering that the farm market is where farmers buy inputs and functions as a local center for farmers to meet up and exchange ideas, farm households located closer have better access to new agricultural technology and market information.

The distance to the nearest town market variable reflects the remoteness of a village to an urban location. Interestingly, the farther away a village is from a city/town, the higher the farm income from crop production. The reason may relate to labor productivity: as households locate farther from an urban area, the fewer off-farm work opportunities are available for farm labor, and the more important farm income is to a household.

Table 5.2 C-D production function IV estimations

Sample size = 145		
Ln(adult female labor)	0.256	
	(0.338)	
Ln(adult male labor)	0.223	
	(0.390)	
Ln(land)	0.281	
	(0.441)	
Head's age	0.013	
	(0.080)	
Head's age squared	-0.0003	
	(0.0008)	
Head's schooling	0.066*	
	(0.038)	
Distance to farm market	-0.161***	
	(0.047)	
Distance to town market	0.087***	
	(0.032)	
	F(8,137) = 6.19	P-value = 0.0000
Marginal products:	R-squared = 0.1275	
Female labor	0.495	
	(0.560)	
Male labor	0.568	
	(0.933)	

***significant at 1% level *significant at 10% level

The equality test of the marginal product of labor and market wage is conducted among those working part-time off-farm. A small sub-sample consisting of 40 individuals is used for the test. The null hypothesis is that the labor market imposes no restrictions on an individual's participation in the wage market, assuming there exist transaction costs occurring for market labor supply. The estimation results show *MPL = 1.159 +0.073 Marketwage*. An F-test rejects the null hypothesis of $(a,b)=(0,1)$ with P-value=0.0002. The significant inequality between the marginal product of labor and market wage strongly indicates that some failures exist in the wage labor market, possibly resulting in binding hours on individuals working off-farm.

5.3.2 Labor Supply Estimation

Total labor supply is summed over the yearly hours of all labor activities including crop and animal production, off-farm work, nonfarm self-employment and home production. Although labor hours spent on home production are omitted in the Chiappori, Fortin and Lacroix study, Donni (2004) shows that their functional form is compatible with models that account for home production. The sharing rule results can be biased when omitting home production[31]. Rapoport, Sofer and Solaz (2009) extend Chiappori, Fortin and Lacroix's method by including home production in collective models. Their results show that collective rationality is rejected and less significant in explanatory variables when omitting home production. They find that women gain more 'power' when home production is included in the model. Their study provides empirical evidence that validates the concern raised in Apps and Rees (1997) that misinterpreting non-market time as pure leisure may lead to misunderstanding of the allocation process of time and resources.

Table 5.3 shows averages and standard deviations (in parentheses) for all work categories of the primary couple. On average, wives spend more time in farm production and almost triple the amount of time on home production than their husbands. For those households engaged in nonfarm self-employment, the yearly hours of husbands working in a nonfarm family business is nearly five times that of their wives. The wage market participation is about even between husband and wife.

---

[31] Donni (2004) states that "*the bias is small when domestic labor supplies are relatively insensitive to wages and/or when leisure demands are very sensitive to income shares*". p.5.

Table 5.3 Labor supply in yearly hours

Sample size = 222 Mean yearly hours in	Wife	Husband
Farm activities	1302.27 (956.06)	1028.81 (1000.00)
Off-farm wage employment	147.08 (540.56)	147.67 (570.77)
Nonfarm self-employment	123.34 (563.54)	610.98 (988.50)
Home production	1076.70 (667.06)	295.12 (504.04)
Total labor hours	2649.38 (1097.28)	2082.58 (1036.56)

Table 5.4 summarizes the marginal products of labor for both husband and wife across the sample. We allow the negative nonlabor income value to reflect a loss from farm production. Table 5.4 also includes wife's age and schooling information and seven more instrumental variables used for estimation of the labor supply functions. Husband's off-farm work participation behavior is used as a dummy instrument entering the wife's labor supply function and vice versa.

We also include three "opinion" dummy variables to measure changes in standard of living for the past three years and interviewees' anticipations for own family standard of living and village economic situations in the near future. The "opinions" dummy variables (see table below) are expected to be correlated with the endogenous shadow wages and nonlabor income, since the awareness of a household's living standard mirrors the wage and income changes. The distribution factor is chosen to be migrants' sex ratio by county and by age. The ratio is computed by the number of migrant males at age j divided by the whole migrant population at age j in each county. The data are subtracted from 2005-2006 labor statistics, National Bureau of Statistics of China (see Appendix A for migrant labor sex ratio by county by age categories).

Table 5.4 Statistic summary for additional variables used in the total labor supply function

	Mean	Std. Dev.	Min	Max
Endogenous variables				
Hourly MPL of wife (yuan)	0.568	0.691	0.042	4.375
Hourly MPL of husband (yuan)	1.264	1.782	0.057	7.164
Nonlabor income (yuan)	2775.244	3537.792	-2426.864	19872.740
Other independent variables				
Husband's age	47.480	9.623	25	70
Husband's schooling (years)	6.844	3.270	0	16
Wife's age	45.532	9.495	23	65
Wife's schooling	4.710	3.570	0	13
Other instruments				
Number of adult males working on-farm	0.198	0.472	0	3
Number of adult females working on-farm	0.113	0.357	0	2
Wife participates in off-farm wage market (Dummy: 1= yes, 0 = no)	0.2	0.401	0	1
Husband participates in off-farm wage market (Dummy: 1= yes, 0 = no)	0.459	0.499	0	1
Household living conditions improved compared to 3 years ago (Dummy: 1= yes, 0 = no)	0.721	0.450	0	1
Anticipate better household living conditions in the near future (Dummy: 1= yes, 0 = no)	0.815	0.389	0	1
Anticipate better village economic situation in the near future (Dummy: 1= yes, 0 = no)	0.802	0.400	0	1
Distribution factor				
Migrants' sex ratio*	0.721	0.045	0.590	0.820

* See Appendix A for the distribution factor by age and county

The generalized method of moments (GMM) is used to estimate the labor supply functions. GMM provides robust estimates regardless the form of covariance matrix of the error term (Chiappori, Fortin and Lacroix, 2002). In other words, efficient estimators are obtained even if the true distribution of the error term is unknown and heteroskedasticity is presented (Greene, 2002). GMM estimation results are reported in table 5.5.

Table 5.5 GMM estimates for labor supply

	Wife	Husband
Ln(MPL of wife)	0.141	-0.208**
	(0.123)	(0.102)
Ln(MPL of husband)	0.152	0.339**
	(0.099)	(0.143)
Ln(MPL of wife) x Ln(MPL of husband)	0.184***	0.229***
	(0.078)	(0.070)
Nonlabor income/1000	0.016	-0.091***
	(0.024)	(0.032)
Ln(land)	-0.074	0.397***
	(0.127)	(0.136)
Age	0.065*	0.010
	(0.039)	(0.074)
Age squared	-0.0009**	-0.0002
	(0.0004)	(0.0005)
Schooling	-0.041***	0.006
	(0.013)	(0.0174)
Migrants' sex ratio	1.695	0.751
	(2.134)	(5.627)
Intercept	5.903***	6.393***
	(1.303)	(2.323)
F-test (prob > F)	*3.16 (0.0013)*	*3.75 (0.0002)*
Hansen J statistic (Prob> χ^2)	*23.784 (0.125)*	*23.500 (0.216)*

***significant at 1% level ** significant at 5% level *significant at 10% level

Positive effects are found for the own marginal product of labor for husband's labor supply behavior. An increase in the wife's MPL, however, has a significant negative effect on husband working hours. Wife's labor supply behavior is not found to be significantly affected by own MPL or husband's MPL. The joint MPL effect is positive on both members' labor supply behaviors at a significance level of 1%.

As nonlabor (pooled) income increases, husbands are found to allocate less time to work, but farm land size positively affects husband's working time. Schooling is a proxy variable used for human capital in the regressions. It has a negative effect on wife's total labor supply, indicating that wives with more education work fewer hours. An F-test shows statistical significance at the 1% level for both labor supply functions. A rejection of the null hypothesis for the Hansen J test indicates that the instruments are validated for the endogeneity issue.

5.3.3 Recovering the Sharing Rule

Table 5.6 presents the partial derivatives of the sharing rule, with standard errors in parentheses. All four variables show statistical significance at 1%. By the definition of the sharing rule, husband and wife agree upon the amount of nonlabor income that s/he is allowed to spend. For every 1 yuan increase in her hourly MPL, her yearly labor income increases by 1573 yuan (at an annual average of hours worked by females), which will lead to a transfer of 4071 yuan to her husband's budget. However, for every 1 yuan increase in his hourly MPL, his yearly labor income increased by 1787 yuan (at an annual average of hours worked by males). It shows that the labor income effect is positive to his sharing of nonlabor income and he gains 1208 yuan as a result. The reason for a positive relation between his MPL and his share of nonlabor income is not straightforward. Although we cannot claim our result describes the real world household situation completely accurately, this result suggests wives behave in a more altruistic manner than husbands, in general. The effect of nonlabor income on wife's labor supply is statistically significant but weak. For every 1 yuan increase in household nonlabor income, her share is increased by 7 cents. The migrants' sex ratio appears to have a large impact on her share of nonlabor income. For every 1 percent increase in the ratio (number of male migrants over the entire population), 13.43 yuan of nonlabor income is transferred to her budget. Again the exact amount of nonlabor income transfer may not be precise, but it complies with the fact that migrant workers receive more labor income than non-migrant workers, in general. A higher wage in the off-farm labor market increases labor supply to the wage market, while reducing his share of nonlabor income. So an increase in the number of male migrants leads to a positive transfer of nonlabor income share to his wife, as expected.

Table 5.6 Sharing rule estimation

Variables	$\partial\phi/\partial Variable$
Hourly MPL of wife	-4071.669
	(462.368)
Hourly MPL of husband	-1208.322
	(205.558)
Nonlabor income	0.073
	(0.000)
Migrants' sex ratio	13.429
	(4.548)

5.3.4 Household Decision-Making

In our questionnaire, we asked 15 questions regarding home and farm production decisions. For each decision-making question, the given options of *who* makes the decision included husband makes decision alone, wife makes decision alone, husband and wife make a joint decision, adult males make a joint decision, adult females make a joint decision, and all adults make a joint decision. The decision-making questions and responses are summarized in the Appendixes B and C. Table 5.7 presents basic statistics for the potentially influential factors for predicting intrahousehold decision-making structure.

The sharing rule ratio is represented by the wife's share of total nonlabor income. Endogeneity between the sharing rule variable and decision-making is a potential concern since the sharing rule may affect intrahousehold decision-making structure and vice versa. Durbin-Wu-Hausman (DWH) tests are conducted to clarify whether instrumental variables are necessary for the decision-making estimations (Hausman, 1978).

Table 5.7 Statistic summary of factors potentially influencing intrahousehold decision-making

Sample size = 156 Variable	Mean	Std. Dev.	Min	Max
Sharing ratio for wife (ϕ / y^*)	0.082	0.052	0.014	0.679
Hourly MPL of wife (yuan)	0.529	0.669	0.042	4.375
Hourly MPL of husband (yuan)	1.116	1.693	0.057	7.164
Age difference (husband's age – wife's age)	1.884	3.090	-8	16
Schooling difference (husband's schooling – wife's schooling)	2.436	3.768	-9	12
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.929	0.257	0	1
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	0.808	0.935	0	1
Wife participates in wage market (Dummy: 1= yes, 0 = no)	0.167	0.734	0	1
Husband participates in wage market (Dummy: 1= yes, 0 = no)	0.423	0.521	0	1
Wife participates in home production (Dummy: 1= yes, 0 = no)	0.929	0.257	0	1
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.391	0.490	0	1
Wife's work distance (km)	12.260	73.568	0	689
Husband's work distance (km)	45.698	215.439	0	2188
Number of other adult females (18 years old and above) in the household	1.058	0.859	0	4
Number of other adult males (18 years old and above) in the household	1.250	1.045	0	5
Work distance of oldest adult child (km)	215.875	327.834	0	1907
Remittances (yuan)	994.551	2430.443	0	20000

According to Davidson and Mackinnon (1993), we first regress the sharing rule ratio over all exogenous variables to predict the residual value for sharing rule ratio. By including the residual of the sharing rule ratio into the original regression model, the augmented regression is used to test whether the parameter of the residual of the sharing rule ratio is significantly different from zero or not. A significant F-test result indicates inconsistent OLS estimates and the existence of endogeneity.

To determine the potential endogeneity of the sharing rule and intrahousehold decision-making structure, the DWH tests are conducted over each decision-making question. The results show that none of the decision-making variables are endogenously determined by the sharing rule ratio, with p-values from 23% to 95%. Appendix D summarizes the DWH test results.

Since the sharing rule represents the share of nonlabor income between spouses, and is derived from labor time allocation, it is one factor that contributes to the household power possessed by either spouse. However, the sharing rule is not exactly the same concept as the individual's power in the household. The higher income he contributes to the household may possibly guarantee his household power dominates over hers in decision-making. Although the sharing rule affects household decision-making structure, who makes decisions may not directly be reflected in the share of nonlabor income.

Both husband and wife's work participation behaviors are recorded as dummies for on-farm, off-farm and home production. Work distance measures the distance from home to the individual's full-time or part-time work location. Zero distance is applied in cases when off-farm work is absent. Other members' influence on household decision-making structure is measured by their presence in the household and the distance they work from home. Other household members are grouped by gender. When multiple adult children (18 years old and above) are present in a household, the oldest adult child's work distance is used to determine the influence that distance of other household members has on a household decision-making structure. The number of observations is reduced to 156, since the inclusion of adult child's work distance eliminates young households without any adult children and households without children answered in the questionnaires.

The significance levels of the exogenous variables on predicting intrahousehold decision-making structure are reported in tables 5.8.1a-5.8.4c. The base outcome is the husband making a decision alone, which is typically assumed to be the prevalent household decision-making structure among Chinese households.

Sharing ratio effect

The sharing rule represents the inequality of intrahousehold resource allocation. A higher sharing rule ratio suggests that more nonlabor (pooled) income is allocated to the wife, which is expected to increase her involvement in household decision making relative to her husband making decisions alone. The sharing rule ratio is found to have a positive and significant effect on the likelihood of the wife's engagement in making six out of fifteen decisions, independently. In the farm production decision-making category, the sharing rule has a statistically significant effect on the wife making decision alone on farm equipment purchase, which is a major farm investment decision. The higher sharing rule ratio also increases her decision-making power in fertilizer usage. However, the results also suggest that many day-to-day production decisions (i.e. what crops to produce, soybean production, livestock types, livestock feed, etc.) are not influenced by the sharing rule ratio.

Table 5.8.1a MNL estimates for intrahousehold decision-making on *production: crop types*

	Crop types				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.205 (0.149)	0.098 (0.131)	-0.046 (0.299)	-0.968 (0.780)	0.241 (0.218)
Hourly MPL of wife (yuan)	-0.954* (0.592)	-0.352 (0.482)	0.567 (0.801)	-2.071 (2.070)	-2.176 (3.220)
Hourly MPL of husband (yuan)	-0.301 (0.230)	-0.182 (0.225)	0.307 (0.327)	-0.257 (0.561)	-0.228 (0.960)
Age difference (husband's age – wife's age)	0.092 (0.083)	0.007 (0.077)	-0.031 (0.173)	-1.166 (0.568)	-0.316 (0.293)
Schooling difference (husband's schooling - wife's schooling)	-0.144 (0.080)	-0.010 (0.066)	-0.013 (0.148)	0.438 (0.319)	-0.649 (0.354)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.403 (1.246)	1.981 (1.521)	33.166 (n.a.)	-1.930 (7.159)	16.478*** (3.774)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.237 (0.927)	-1.361 (0.932)	-0.330 (1.861)	-6.638* (3.806)	-0.726 (2.201)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	0.546 (1.657)	1.621 (1.586)	-1.085 (2.612)	-5.677 (8.200)	-40.258 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.755*** (0.695)	-.026 (0.666)	0.197 (1.483)	1.752 (2.466)	-48.000 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-52.686*** (13.763)	-52.635*** (13.753)	-55.771*** (13.720)	-51.754*** (12.583)	-32.476 (n.a.)
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.125 (0.628)	0.215 (0.538)	-1.522 (1.376)	-0.498 (2.461)	-1.515 (1.438)
Wife's work distance (km)	-0.054 (0.138)	-0.053 (0.138)	0.008 (0.205)	0.074 (0.161)	-0.0178 (n.a.)
Husband's work distance (km)	0.003 (0.005)	0.005 (0.005)	-0.062 (0.157)	-0.122 (0.077)	0.003 (n.a.)
Number of other adult females (18 years old and above) in the household	0.011 (0.327)	0.171 (0.282)	-0.879 (0.701)	-3.018 (1.996)	-.363 (0.910)
Number of other adult males (18 years old and above) in the household	-0.141 (0.250)	-0.177 (0.235)	-1.542*** (0.628)	-0.786 (0.974)	1.245 (0.811)
Work distance of oldest adult child (km)	0.026 (0.074)	-0.034 (0.074)	0.030 (0.166)	0.525 (0.384)	-0.022 (0.165)
Remittances (yuan)	0.182 (0.122)	0.055 (0.122)	0.223 (0.242)	-0.233 (n.a.)	-0.196 (0.627)
LRchi2 (Prob >chi2)	134.75 (0.0005)				
Pseudo R2	0.2923				

***significant at 1% level ** significant at 5% level *significant at 10% level
n.a. Extreme values for the standard errors indicate that little confidence can be placed in the estimated coefficient. In cases where a column is indicated by n.a., there are too few observations for the particular choice to allow inclusion and appropriate estimation.

Table 5.8.1b MNL estimates for intrahousehold decision-making on *production: soybean production*

	Soybean production				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.210 (0.146)	0.084 (0.123)	0.217 (0.462)	n.a	0.127 (0.250)
Hourly MPL of wife (yuan)	-1.456* (0.851)	-0.181 (0.441)	3.113 (2.062)	n.a	-2.479 (3.656)
Hourly MPL of husband (yuan)	-0.186 (0.256)	-0.262 (0.241)	2.079 (1.370)	n.a	0.080 (0.734)
Age difference (husband's age – wife's age)	-0.056 (0.099)	-0.028 (0.076)	0.162 (0.328)	n.a	0.111 (0.181)
Schooling difference (husband's schooling - wife's schooling)	-0.101 (0.082)	0.0284 (0.064)	0.129 (0.324)	n.a	-0.392 (0.267)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.986 (1.401)	1.620 (1.256)	0.394 (227.498)	n.a	15.148 (n.a.)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.454 (1.007)	-1.267 (0.951)	5.163 (8.460)	n.a	0.183 (2.239)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-1.155 (1.715)	0.222 (0.809)	-57.578 (334.514)	n.a	-39.615 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.802*** (0.824)	0.387 (0.689)	-1.995 (2.605)	n.a	-44.178 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-4.590* (2.615)	-4.041* (2.262)	-16.058** (7.254)	n.a	13.180 (n.a.)
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.748 (0.708)	0.524 (0.535)	-4.768 (3.817)	n.a	-1.450 (1.710)
Wife's work distance (km)	-0.066 (0.174)	-0.011 (0.013)	0.239 (0.782)	n.a	0.071 (n.a.)
Husband's work distance (km)	0.004 (0.011)	0.009 (0.011)	-0.172 (0.347)	n.a	0.008 (n.a.)
Number of other adult females (18 years old and above) in the household	-0.580 (0.375)	-0.237 (0.271)	-3.260* (1.960)	n.a	-1.045 (0.833)
Number of other adult males (18 years old and above) in the household	-0.291 (0.275)	-0.101 (0.233)	-5.139* (2.783)	n.a	1.080 (0.882)
Work distance of oldest adult child (km)	0.089 (0.081)	-0.006 (0.078)	-0.028 (0.358)	n.a	0.035 (0.157)
Remittances (yuan)	0.018 (0.013)	-0.002 (0.014)	0.101* (0.054)	n.a .	-0.036 (0.027)
LRchi2 (Prob >chi2)	181.10 (0.0000)				
Pseudo R2	0.4009				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.1c MNL estimates for intrahousehold decision-making on *production: livestock types*

	Livestock types				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.198 (0.146)	0.175 (0.144)	-0.505 (0.328)	-0.269 (0.343)	0.253 (0.251)
Hourly MPL of wife (yuan)	1.482 (1.110)	1.795* (1.108)	3.161** (1.527)	1.211 (1.597)	-1.936 (4.217)
Hourly MPL of husband (yuan)	-0.261 (0.256)	-0.401 (0.273)	1.484** (0.767)	-0.194 (0.472)	0.064 (0.881)
Age difference (husband's age – wife's age)	0.009 (0.087)	0.001 (0.086)	-0.170 (0.250)	-0.377* (0.214)	-0.309 (0.297)
Schooling difference (husband's schooling - wife's schooling)	-0.028 (0.081)	0.069 (0.078)	0.251 (0.240)	0.106 (0.154)	-0.522 (0.341)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	2.193 (1.271)	3.474** (1.526)	16.208*** (6.952)	3.105 (3.823)	16.828*** (4.011)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.015 (1.018)	-1.326 (1.043)	1.432 (5.409)	-2.270 (1.622)	-0.538 (2.122)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-4.196*** (1.703)	-3.093* (1.667)	-53.247 (n.a.)	-6.999 (4.426)	-44.636 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.293*** (0.943)	1.908** (0.954)	1.161 (2.608)	3.341** (1.673)	-46.578 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-20.587*** (6.364)	-21.139*** (6.349)	-0.329 (n.a.)	-18.452*** (5.676)	-0.852 (n.a.)
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.433 (0.644)	0.793 (0.639)	-0.815 (1.626)	-0.044 (1.474)	-0.801 (1.514)
Wife's work distance (km)	0.222 (0.156)	0.220 (0.156)	0.127 (n.a.)	0.285* (0.161)	0.002 (n.a.)
Husband's work distance (km)	0.012 (0.043)	0.014 (0.043)	-0.594 (0.540)	-0.049 (0.057)	-0.193 (n.a.)
Number of other adult females (18 years old and above) in the household	0.128 (0.341)	0.367 (0.335)	-2.691** (1.328)	-0.246 (1.010)	-0.539 (0.956)
Number of other adult males (18 years old and above) in the household	-0.399 (0.275)	-0.227 (0.277)	-2.661*** (1.049)	-0.426 (0.505)	0.836 (0.840)
Work distance of oldest adult child (km)	0.052 (0.083)	-0.024 (0.089)	0.029 (0.254)	0.139 (0.195)	0.039 (0.151)
Remittances (yuan)	0.107 (0.144)	0.029 (0.151)	0.716 (0.399)	-0.281 (n.a.)	-0.057 (0.617)
LRchi2 (Prob >chi2)	126.18 (0.0025)				
Pseudo R2	0.2826				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.1d MNL estimates for intrahousehold decision-making on *production: livestock feed*

	Livestock feed				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.121 (0.137)	0.093 (0.138)	-0.243 (0.320)	-0.427 (0.300)	0.190 (0.242)
Hourly MPL of wife (yuan)	0.634 (0.780)	0.712 (0.815)	3.407** (1.507)	1.031 (1.198)	-2.551 (4.111)
Hourly MPL of husband (yuan)	-0.338 (0.240)	-0.497* (0.281)	1.750* (0.949)	-0.369 (0.410)	0.116 (0.895)
Age difference (husband's age – wife's age)	0.041 (0.083)	0.036 (0.087)	-0.401 (0.326)	-0.133 (0.161)	-0.261 (0.287)
Schooling difference (husband's schooling - wife's schooling)	-0.073 (0.079)	0.055 (0.080)	0.379 (0.298)	0.102 (0.140)	-0.518* (0.310)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	2.614** (1.312)	1.994* (1.273)	4.749 (135.545)	19.603*** (2.993)	16.745*** (3.950)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-0.977 (0.963)	-1.591 (1.040)	3.164 (6.608)	-2.971** (1.472)	-0.614 (2.077)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-2.877* (1.568)	-2.217 (1.614)	-48.478 (n.a.)	-36.753 (n.a.)	-32.450 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.978** (0.926)	0.856 (1.003)	-0.607 (2.795)	1.424 (1.396)	-34.798 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-20.615 (10720.1)	-21.513 (10720.1)	9.890 (n.a.)	0.279 (n.a.)	-1.101 (n.a.)
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.068 (0.597)	1.019* (0.627)	-0.837 (1.828)	0.232 (1.176)	-.843 (1.476)
Wife's work distance (km)	0.198 (0.156)	0.197 (0.156)	0.643 (0.774)	0.246 (n.a.)	0.269 (n.a.)
Husband's work distance (km)	0.047 (0.068)	0.050 (0.068)	-0.291 (0.512)	0.030 (0.077)	0.048 (n.a.)
Number of other adult females (18 years old and above) in the household	0.376 (0.330)	0.315 (0.341)	-3.150** (1.599)	-0.387 (0.695)	-0.448 (0.897)
Number of other adult males (18 years old and above) in the household	-0.482* (0.256)	-0.714*** (0.290)	-2.578** (1.261)	-0.867* (0.473)	0.691 (0.832)
Work distance of oldest adult child (km)	0.002 (0.075)	-0.165* (0.095)	0.244 (0.271)	0.066 (0.138)	-0.021 (0.152)
Remittances (yuan)	n.a.	n.a.	n.a.	n.a.	n.a.
LRchi2 (Prob >chi2)	126.80 (0.0007)				
Pseudo R2	0.2834				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.1e MNL estimates for intrahousehold decision-making on *production: farm equipment purchases*

	Farm equipment purchases				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.397** (0.192)	0.214 (0.144)	0.382* (0.225)	n.a.	0.376* (0.226)
Hourly MPL of wife (yuan)	-4.969** (2.483)	0.360 (0.420)	0.748 (0.812)	n.a.	-0.588 (1.784)
Hourly MPL of husband (yuan)	0.125 (0.279)	0.070 (0.184)	0.838* (0.463)	n.a.	-0.615 (1.853)
Age difference (husband's age – wife's age)	-0.015 (0.109)	-0.022 (0.076)	-0.053 (0.166)	n.a.	-0.133 (0.206)
Schooling difference (husband's schooling - wife's schooling)	-0.111 (0.103)	0.038 (0.060)	0.249 (0.168)	n.a.	-0.291 (0.215)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	-0.869 (1.656)	0.921 (1.228)	92.431 (85.012)	n.a.	21.198 (85.458)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-0.637 (0.975)	-0.384 (0.762)	0.515 (2.126)	n.a.	-2.709 (1.759)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-44.093 (n.a.)	-0.037 (0.718)	-7.277 (6.852)	n.a.	-40.332 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.614* (0.905)	-0.002 (0.537)	0.955 (1.713)	n.a.	-42.517 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-3.545 (2.821)	-24.79 (85.423)	-26.351 (85.640)	n.a.	-26.361 (85.459)
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.010 (0.791)	0.650 (0.509)	-1.268 (1.301)	n.a.	-0.518 (1.166)
Wife's work distance (km)	0.023 (n.a.)	-0.005 (0.015)	0.541 (0.457)	n.a.	0.051 (n.a.)
Husband's work distance (km)	-0.004 (0.003)	0.0001 (0.001)	-0.555* (0.309)	n.a.	-0.002 (n.a.)
Number of other adult females (18 years old and above) in the household	-0.846 (0.482)	-0.333 (0.261)	-1.506* (0.840)	n.a.	-0.162 (0.685)
Number of other adult males (18 years old and above) in the household	-0.238 (0.292)	-0.229 (0.216)	-0.765 (0.503)	n.a.	0.291 (0.546)
Work distance of oldest adult child (km)	-0.035 (0.090)	-0.015 (0.064)	-0.010 (0.177)	n.a.	-0.070 (0.164)
Remittances (yuan)	-0.131 (0.208)	0.007 (0.082)	0.417** (0.197)	n.a.	-0.007 (0.411)
LRchi2 (Prob >chi2)	156.91 (0.0000)				
Pseudo R2	0.3585				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.1f MNL estimates for intrahousehold decision-making on *production: fertilizer usage*

	Fertilizer usage				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.219* (0.136)	0.053 (0.121)	0.281* (0.162)	-0.361 (0.347)	n.a.
Hourly MPL of wife (yuan)	-1.234 (0.934)	0.441 (0.458)	1.252 (0.825)	1.024 (1.291)	n.a.
Hourly MPL of husband (yuan)	0.014 (0.219)	-0.389 (0.263	0.430 (0.348)	-0.182 (0.417)	n.a.
Age difference (husband's age – wife's age)	-0.048 (0.099)	-0.047 (0.074)	0.088 (0.153)	-0.307 (0.205)	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.148* (0.090)	0.010 (0.067)	0.151 (0.167)	0.085 (0.150)	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.857 (1.546)	1.570 (1.290)	28.875 (29.243)	3.037 (5.332)	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-2.046** (0.941)	-2.002** (0.937)	0.017 (2.091)	-2.697* (1.496)	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-0.573 (1.790)	-0.319 (0.858)	-3.627 (2.413)	-5.854 (7.355)	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.294*** (0.746)	0.556 (0.628)	0.551 (1.585)	2.636* (1.480)	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-24.164 (29.134)	-23.858 (29.236)	-27.328 (29.635)	-21.123 (29.767)	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.721 (0.724)	1.002* (0.548)	-1.439 (1.441)	0.138 (1.493)	n.a.
Wife's work distance (km)	-0.070 (0.188)	-0.005 (0.024)	0.157 (0.170)	0.072 (0.064)	n.a.
Husband's work distance (km)	-0.003* (0.001)	-0.0001 (0.001)	-0.167 (0.167)	-0.073 (0.052)	n.a.
Number of other adult females (18 years old and above) in the household	-0.672* (0.398)	-0.328 (0.280)	-1.159 (0.792)	-0.545 (0.879)	n.a.
Number of other adult males (18 years old and above) in the household	-0.128 (0.271)	-0.216 (0.229)	-1.415** (0.612)	-0.248 (0.477)	n.a.
Work distance of oldest adult child (km)	0.098 (0.077)	-0.0042 (0.076)	-0.093 (0.220)	0.111 (0.200)	n.a.
Remittances (yuan)	0.012 (0.011)	-0.006 (0.012)	0.032 (0.023)	-0.185 (n.a.)	n.a.
LRchi2 (Prob >chi2)	155.46 (0.0000)				
Pseudo R2	0.3487				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.1g MNL estimates for intrahousehold decision-making on *production: pesticide/herbicide usage*

	Pesticide/ herbicides usage				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.175 (0.132)	0.729 (0.119)	0.213 (0.153)	-0.442 (0.386)	n.a.
Hourly MPL of wife (yuan)	-1.523 (1.032)	0.406 (0.460)	1.004 (0.762)	2.091 (1.494)	n.a.
Hourly MPL of husband (yuan)	0.100 (0.216)	-0.390 (0.274	0.487 (0.326)	-0.321 (0.442)	n.a.
Age difference (husband's age – wife's age)	-0.031 (0.099)	-0.080 (0.076)	0.016 (0.147)	-0.245 (0.207)	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.182** (0.093)	0.080 (0.066)	0.101 (0.145)	0.138 (0.169)	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.068 (91.500)	1.265 (1.258)	18.752 (15.256)	20.074 (n.a.)	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.262 (0.904)	-1.537* (0.924)	0.504 (1.961)	-2.663* (1.589)	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	0.282 (1.727)	-0.272 (0.858)	-3.087 (2.069)	-40.981 (n.a.)	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.652** (0.712)	0.563 (0.643)	0.227 (1.287)	2.301 (1.498)	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-25.115* (15.640)	-24.91 (15.662)	-27.994* (16.096)	-6.287 (n.a.)	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.016 (0.711)	0.867 (0.546)	-0.552 (1.097)	0.261 (1.624)	n.a.
Wife's work distance (km)	-0.117 (0.187)	-0.010 (0.025)	0.113 (0.111)	0.027 (n.a.)	n.a.
Husband's work distance (km)	0.002 (0.005)	0.004 (0.005)	-0.124 (0.108)	-0.783 (0.931)	n.a.
Number of other adult females (18 years old and above) in the household	-0.991*** (0.417)	-0.278 (0.283)	-1.257* (0.693)	-0.783 (0.931)	n.a.
Number of other adult males (18 years old and above) in the household	-0.303 (0.271)	-0.207 (0.230)	-1.310** (0.553)	-0.242 (0.492)	n.a.
Work distance of oldest adult child (km)	0.150** (0.080)	-0.049 (0.082)	0.088 (0.169)	0.162 (0.214)	n.a.
Remittances (yuan)	0.111 (0.128)	-0.049 (0.130)	0.139 (0.212)	-0.187 (n.a.)	n.a.
LRchi2 (Prob >chi2)	158.60 (0.0000)				
Pseudo R2	0.3534				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.2a MNL estimates for intrahousehold decision-making on *marketing: market crops*

	Market crops				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.246* (0.142)	0.157 (0.135)	0.237* (0.147)	-0.395 (0.392)	n.a.
Hourly MPL of wife (yuan)	-.756 (1.152)	1.090** (0.562)	1.038 (0.707)	2.466* (1.541)	n.a.
Hourly MPL of husband (yuan)	0.102 (0.228)	-0.118 (0.226)	0.221 (0.300)	-0.240 (0.444)	n.a.
Age difference (husband's age – wife's age)	0.097 (0.091)	0.056 (0.078)	0.0002 (0.132)	-0.160 (0.202)	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.048 (0.085)	0.105 (0.069)	0.002 (0.121)	0.167 (0.167)	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.761 (1.455)	1.434 (1.277)	19.301 (21.137)	20.327 (n.a.)	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.098 (0.872)	-0.077 (0.936)	-0.372 (1.495)	-2.155 (1.592)	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	1.758 (1.539)	0.216 (0.895)	-1.989 (1.916)	-41.517 (n.a.)	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.245*** (0.742)	1.565** (0.686)	1.316 (1.328)	2.862 (1.518)	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-25.381*** (2.293)	-24.566*** (2.511)	-25.623*** (2.770)	-5.326 (n.a.)	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.635 (0.685)	0.918 (0.581)	-0.226 (0.927)	0.343 (1.632)	n.a.
Wife's work distance (km)	-0.256 (0.174)	-0.007 (0.011)	0.106 (0.122)	0.031 (n.a.)	n.a.
Husband's work distance (km)	-0.002 (0.001)	-0.0001 (0.001	-0.119 (0.122)	-0.012 (0.028)	n.a.
Number of other adult females (18 years old and above) in the household	-0.812** (0.388)	-0.054 (0.279)	-0.971* (0.542)	-0.653 (0.923)	n.a.
Number of other adult males (18 years old and above) in the household	-0.013 (0.265)	-0.272 (0.248)	-0.965** (0.431)	-0.147 (0.486)	n.a.
Work distance of oldest adult child (km)	0.12 (0.078)	-0.078 (0.086)	-0.056 (0.148)	0.151 (0.212)	n.a.
Remittances (yuan)	0.072 (0.109)	-0.072 (0.132)	0.316** (0.165)	-0.198 (n.a.)	n.a.
LRchi2 (Prob >chi2)	158.70 (0.0000)				
Pseudo R2	0.3437				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.2b MNL estimates for intrahousehold decision-making on *marketing: market livestock*

	Market livestock				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.268* (0.147)	0.169 (0.135)	0.305** (0.155)	-0.359 (0.391)	n.a.
Hourly MPL of wife (yuan)	-2.533 (1.623)	1.146** (0.555)	1.377* (0.786)	2.367 (1.536)	n.a.
Hourly MPL of husband (yuan)	0.187 (0.229)	-0.058 (0.221)	0.429 (0.315)	-0.175 (0.443)	n.a.
Age difference (husband's age – wife's age)	-0.017 (0.104)	0.045 (0.078)	0.058 (0.143)	-0.178 (0.203)	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.098 (0.089)	0.122* (0.068)	0.096 (0.133)	0.160 (0.168)	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	0.406 (1.641)	1.430 (1.253)	22.548 (23.591)	20.756*** (3.356)	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.386* (0.873)	-0.194 (0.916)	0.072 (1.640)	-2.234 (1.574)	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	1.850 (1.682)	-0.043 (0.833)	-2.592 (2.083)	-46.583 (n.a.)	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.023*** (0.737)	1.084* (0.636)	0.674 (1.378)	2.478* (1.491)	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-26.663 (23.546)	-25.396 (23.501)	-26.665 (23.703)	-5.608 (n.a.)	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	0.332 (0.717)	0.946* (0.566)	-.525 (1.064)	0.262 (1.641)	n.a.
Wife's work distance (km)	-0.369* (0.214)	-0.007 (0.013)	0.124 (0.136)	-0.344 (n.a.)	n.a.
Husband's work distance (km)	-0.003** (0.001)	-0.0002 (0.001)	-0.137 (0.135)	-0.011 (0.028)	n.a.
Number of other adult females (18 years old and above) in the household	-0.851** (0.417)	-0.129 (0.273)	-1.096* (0.654)	-0.651 (0.927)	n.a.
Number of other adult males (18 years old and above) in the household	-0.058 (0.269)	-0.282 (0.237)	-0.695 (0.449)	-0.139 (0.492)	n.a.
Work distance of oldest adult child (km)	0.097 (0.078)	-0.015 (0.0076)	0.325 (0.153)	0.147 (0.208)	n.a.
Remittances (yuan)	0.113 (0.109)	0.004 (0.101)	0.142 (0.204)	-0.305 (n.a.)	n.a.
LRchi2 (Prob >chi2)	161.80 (0.0000)				
Pseudo R2	0.3543				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.2c MNL estimates for intrahousehold decision-making on *marketing: contract farming*

	Contract farming				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.408** (0.188)	0.174 (0.140)	0.467** (0.210)	n.a.	0.398* (0.239)
Hourly MPL of wife (yuan)	-2.867 (1.874)	0.325 (0.433)	1.055 (0.831)	n.a.	-0.572 (1.784)
Hourly MPL of husband (yuan)	0.207 (0.245)	-0.050 (0.198)	0.537 (0.352)	n.a.	-0.846 (1.998)
Age difference (husband's age – wife's age)	0.039 (0.113)	-0.015 (0.074)	0.101 (0.155)	n.a.	-0.105 (0.206)
Schooling difference (husband's schooling - wife's schooling)	-0.172* (0.107)	0.062 (0.060)	0.132 (0.170)	n.a.	-0.311 (0.218)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	-0.625 (1.649)	0.957 (1.226)	32.999 (30.906)	n.a.	21.705 (n.a.)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-0.735 (0.929)	-0.313 (0.794)	0.980 (2.089)	n.a.	-2.694 (1.782)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-1.235 (3.447)	0.057 (0.706)	-3.663 (2.498)	n.a.	-43.484 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.032 (0.831)	0.406 (0.517)	0.218 (1.574)	n.a.	-46.406 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-5.018* (2.799)	-25.431*** (3.502)	-28.794*** (3.777)	n.a.	-7.416*** (3.235)
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.775 (0.848)	0.680 (0.503)	-2.302 (1.547)	n.a.	-0.751 (1.175)
Wife's work distance (km)	-0.109 (0.409)	-0.004 (0.013)	0.183 (0.174)	n.a.	-.003 (n.a.)
Husband's work distance (km)	-0.002 (0.002)	0.0001 (0.001)	-0.192 (0.172)	n.a.	-0.124 (0.682)
Number of other adult females (18 years old and above) in the household	-0.741 (0.465)	-0.277 (0.257)	-1.103 (0.787)	n.a.	0.294 (0.554)
Number of other adult males (18 years old and above) in the household	-0.169 (0.306)	-0.203 (0.212)	-1.292** (0.592)	n.a.	0.294 (0.554)
Work distance of oldest adult child (km)	-0.026 (0.098)	0.015 (0.062)	-0.115 (0.209)	n.a.	-0.054 (0.164)
Remittances (yuan)	0.197 (0.120)	0.020 (0.092)	0.396* (0.236)	n.a.	0.012 (0.399)
LRchi2 (Prob >chi2)	151.25 (0.0000)				
Pseudo R2	0.3473				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.3a MNL estimates for intrahousehold decision-making on *innovation: new crop cultivars adoption*

	New crop cultivars adoption				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.189 (0.140)	0.020 (0.121)	0.291 (0.201)	-1.030 (0.836)	n.a.
Hourly MPL of wife (yuan)	-1.623 (1.052)	0.282 (0.481)	0.994 (0.892)	3.773 (3.440)	n.a.
Hourly MPL of husband (yuan)	-0.216 (0.264)	-0.473* (0.275)	0.928 (0.652)	-0.203 (0.569)	n.a.
Age difference (husband's age – wife's age)	-0.058 (0.108)	-0.022 (0.079)	-0.043 (0.202)	-0.720 (0.550)	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.115 (0.090)	0.054 (0.071)	0.315 (0.208)	0.618 (0.400)	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	1.020 (1.484)	1.899 (1.308)	136.575** (71.809)	2.242 (14.782)	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.520 (1.068)	-1.401 (1.021)	0.284 (2.788)	-5.988* (3.374)	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-1.703 (1.829)	-0.751 (1.096)	-11.438* (6.741)	-20.982 (2801.822)	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	3.667*** (1.023)	1.609* (0.883)	3.065 (2.036)	3.811 (2.643)	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-26.376 (72.948)	-26.179 (72.934)	-28.999 (73.392)	-11.952 (2802.599)	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	1.325* (0.781)	0.991* (0.586)	-1.366 (1.594)	0.421 (2.894)	n.a.
Wife's work distance (km)	-0.074 (0.176)	-0.032 (0.056)	0.818* (0.451)	0.265 (0.192)	n.a.
Husband's work distance (km)	0.022 (0.047)	0.023 (0.047)	-0.827* (0.440)	-0.231 (0.153)	n.a.
Number of other adult females (18 years old and above) in the household	-0.615 (0.400)	-0.338 (0.288)	-1.797* (0.997)	-3.262 (2.077)	n.a.
Number of other adult males (18 years old and above) in the household	-0.505* (0.296)	-0.272 (0.246)	-1.585** (0.673)	-0.740 (1.042)	n.a.
Work distance of oldest adult child (km)	0.107 (0.086)	-0.047 (0.084)	-0.027 (0.244)	0.596 (0.481)	n.a.
Remittances (yuan)	0.006 (0.014)	-0.002 (0.014)	0.067* (0.026)	-0.205 (n.a.)	n.a.
LRchi2 (Prob >chi2)	205.39 (0.0000)				
Pseudo R2	0.4465				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.3b MNL estimates for intrahousehold decision-making on *innovation: try new ideas on the farm*

	Try new ideas on the farm				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.235 (0.159)	0.536 (0.134)	0.271 (0.176)	n.a.	n.a.
Hourly MPL of wife (yuan)	-4.085** (1.861)	0.302 (0.460)	0.671 (0.730)	n.a.	n.a.
Hourly MPL of husband (yuan)	-0.018 (0.245)	-0.160 (0.212)	0.315 (0.331)	n.a.	n.a.
Age difference (husband's age – wife's age)	-0.028 (0.107)	-0.056 (0.076)	0.030 (0.144)	n.a.	n.a.
Schooling difference (husband's schooling - wife's schooling)	-0.181* (0.099)	0.090 (0.065)	0.060 (0.147)	n.a.	n.a.
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	-0.581 (1.580)	1.153 (1.238)	27.283 (26.445)	n.a.	n.a.
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.070 (0.934)	-0.280 (0.859)	0.297 (1.758)	n.a.	n.a.
Wife participates in wage market (Dummy: 1= yes, 0 = no)	2.484 (1.846)	1.016 (0.838)	-2.256 (2.291)	n.a.	n.a.
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.911*** (0.806)	0.849 (0.596)	0.531 (1.469)	n.a.	n.a.
Wife participates in home production (Dummy: 1= yes, 0 = no)	-24.656 (26.431)	-23.953 (26.408)	-26.387 (26.773)	n.a.	n.a.
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.319 (0.774)	0.952* (0.542)	-2.035 (1.399)	n.a.	n.a.
Wife's work distance (km)	-0.340 (0.238)	-0.006 (0.015)	0.153 (0.151)	n.a.	n.a.
Husband's work distance (km)	-0.004 (0.003)	0.0001 (0.001)	-0.165 (0.149)	n.a.	n.a.
Number of other adult females (18 years old and above) in the household	-0.848** (0.436)	-0.276 (0.264)	-0.961 (0.686)	n.a.	n.a.
Number of other adult males (18 years old and above) in the household	-0.418 (0.292)	-0.296 (0.216)	-0.990** (0.498)	n.a.	n.a.
Work distance of oldest adult child (km)	0.059 (0.098)	-0.033 (0.0066)	-0.164 (0.196)	n.a.	n.a.
Remittances (yuan)	0.0002* (0.0001)	-0.021 (0.098)	0.325 (0.221)	n.a.	n.a.
LRchi2 (Prob >chi2)	178.73 (0.0000)				
Pseudo R2	0.4072				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.3c MNL estimates for intrahousehold decision-making on *innovation: try new ideas at home*

	Try new ideas at home				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.279* (0.163)	0.123 (0.140)	0.300* (0.177)	n.a.	0.261 (0.235)
Hourly MPL of wife (yuan)	-2.387* (1.485)	0.440 (0.451)	0.545 (0.675)	n.a.	-0.652 (1.991)
Hourly MPL of husband (yuan)	0.051 (0.220)	-0.044 (0.207)	0.370 (0.317)	n.a.	-0.380 (1.589)
Age difference (husband's age – wife's age)	0.066 (0.099)	-0.007 (0.077)	0.045 (0.131)	n.a.	-0.110 (0.209)
Schooling difference (husband's schooling - wife's schooling)	-0.159* (0.099)	0.106* (0.063)	0.082 (0.132)	n.a.	-0.287 (0.224)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	-0.762 (1.448)	0.873 (1.261)	31.573 (25.339)	n.a.	20.590 (25.611)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	0.561 (0.883)	0.406 (0.840)	0.970 (1.656)	n.a.	-2.334 (1.703)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-0.419 (1.078)	0.553 (0.764)	-2.577 (2.180)	n.a.	-42.36 (n.a.)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.088*** (0.732)	0.596 (0.581)	0.544 (1.411)	n.a.	-45.212 (n.a.)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-0.554 (n.a.)	-23.917 (25.309)	-26.09 (25.762)	n.a.	-26.18 (25.568)
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.090 (0.741)	0.835 (0.528)	-1.302 (1.115)	n.a.	-0.251 (1.195)
Wife's work distance (km)	-0.0006 (0.034)	-0.004 (0.011)	0.180 (0.144)	n.a.	0.049 (n.a.)
Husband's work distance (km)	-0.002 (0.002)	0.0003 (0.001)	-0.190 (0.142)	n.a.	-0.006 (n.a.)
Number of other adult females (18 years old and above) in the household	-0.725* (0.409)	-0.276 (0.268)	-0.955 (0.620)	n.a.	-0.141 (0.715)
Number of other adult males (18 years old and above) in the household	-0.168 (0.277)	-0.261 (0.223)	-0.661 (0.423)	n.a.	0.205 (0.571)
Work distance of oldest adult child (km)	-0.029 (0.086)	-0.006 (0.066)	-0.001 (0.002)	n.a.	-0.015 (0.151)
Remittances (yuan)	0.117 (0.107)	-0.062 (0.100)	0.306* (0.175)	n.a.	0.004 (0.383)
LRchi2 (Prob >chi2)	147.82 (0.0000)				
Pseudo R2	0.3302				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.4a MNL estimates for intrahousehold decision-making on *consumption*: *food purchase*

	Food purchase				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.205 (0.147)	0.160 (0.147)	0.335 (0.469)	-0.049 (0.252)	0.150 (0.158)
Hourly MPL of wife (yuan)	1.639 (1.066)	2.179** (1.064)	-2.416 (3.605)	1.837 (1.456)	0.825 (1.279)
Hourly MPL of husband (yuan)	-0.420* (0.246)	-0.419 (0.263)	0.717 (0.894)	-0.190 (0.410)	-0.273 (0.342)
Age difference (husband's age – wife's age)	0.106 (0.089)	0.017 (0.090)	-0.544 (0.342)	-0.125 (0.165)	-0.045 (0.134)
Schooling difference (husband's schooling - wife's schooling)	0.085 (0.081)	0.112 (0.079)	0.742** (0.362)	0.079 (0.132)	-0.081 (0.119)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	3.240* (1.966)	3.676** (1.890)	-0.882 (11.778)	20.023*** (3.013)	-0.919 (1.403)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.562 (1.013)	-1.073 (1.078)	1.086 (4.629)	-2.868** (1.5152)	-2.774*** (1.160)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-2.076 (1.586)	-2.229 (1.605)	-10.783 (14.194)	-47.949 (0.000)	-3.603* (2.251)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	1.820** (0.779)	1.807** (0.781)	-0.328 (2.194)	0.810 (1.401)	1.154 (1.021)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-22.311 (17.457)	-21.290 (17.472)	-18.287 (13.746)	0.485 (0.000)	-23.431 (17.450)
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.243 (0.661)	1.078* (0.626)	-8.404 (12.344)	-0.093 (1.076)	0.579 (0.846)
Wife's work distance (km)	0.281 (0.210)	0.287 (0.210)	0.458* (0.256)	0.330 (0.000)	0.281 (0.210)
Husband's work distance (km)	-0.001 (0.002)	-0.001 (0.002)	-0.163 (0.136)	-0.018 (0.035)	-0.001 (0.001
Number of other adult females (18 years old and above) in the household	0.563* (0.338)	0.238 (0.339)	-3.913* (2.118)	0.121 (0.654)	-0.194 (0.576)
Number of other adult males (18 years old and above) in the household	-0.278 (0.264)	-0.141 (0.255)	-1.426* (0.881)	-0.432 (0.450)	-0.415 (0.356)
Work distance of oldest adult child (km)	-0.064 (0.001)	0.009 (0.078)	0.145 (0.293)	0.092 (0.170)	-0.088 (0.197)
Remittances (yuan)	0.073 (0.1084)	-0.1275 (0.134)	0.485 (0.443)	-0.799 (0.741)	-0.764 (0.562)
LRchi2 (Prob >chi2)	126.670 (0.0023)				
Pseudo R2	0.263				

***significant at 1% level ** significant at 5% level *significant at 10% level

Table 5.8.4b MNL estimates for intrahousehold decision-making on *consumption: food consumption*

	Food consumption				
	W	H&W	M	F	ALL
Sharing ratio for wife (ϕ / y^*)	0.130 (0.142)	0.069 (0.146)	0.282 (0.435)	-0.049 (0.249)	0.089 (0.150)
Hourly MPL of wife (yuan)	1.932 (1.453)	1.835 (1.462)	-2.370 (3.900)	2.675* (1.561)	-2.568 (2.452)
Hourly MPL of husband (yuan)	-0.448 (0.283)	-0.338 (0.293)	0.636 (0.912)	-0.205 (0.415)	-0.259 (0.403)
Age difference (husband's age – wife's age)	-0.022 (0.092)	-0.109 (0.095)	-0.626* (0.348)	-0.162 (0.150)	-0.290* (0.161)
Schooling difference (husband's schooling - wife's schooling)	0.153* (0.094)	0.134 (0.094)	0.740 (0.361)	0.118 (0.136)	-0.081 (0.138)
Wife participates on-farm work (Dummy: 1= yes, 0 = no)	3.748** (1.848)	2.858* (1.571)	-0.206 (12.653)	21.230*** (3.029)	-2.422 (1.830)
Husband participates on-farm work (Dummy: 1= yes, 0 = no)	-1.182 (1.095)	-0.829 (1.145)	1.084 (4.861)	-2.946* (1.611)	-2.242* (1.300)
Wife participates in wage market (Dummy: 1= yes, 0 = no)	-2.257 (1.742)	-2.383 (1.789)	-10.943 (15.298)	-37.539 (0.00002)	-2.168 (2.228)
Husband participates in wage market (Dummy: 1= yes, 0 = no)	2.105** (0.939)	1.508 (0.963)	-0.161 (2.241)	0.408 (1.544)	0.304 (1.235)
Wife participates in home production (Dummy: 1= yes, 0 = no)	-21.194 (18.818)	-21.186 (18.817)	-17.064 (14.575)	0.377 (n.a.)	5.120 (n.a.)
Husband participates in home production (Dummy: 1= yes, 0 = no)	-0.127 (0.724)	1.154* (0.706)	-8.532 (13.243)	0.516 (1.053)	-0.372 (0.926)
Wife's work distance (km)	0.402 (0.342)	0.403 (0.343)	0.577 (0.377)	0.448 (1.447)	0.410 (0.343)
Husband's work distance (km)	0.010 (0.036)	0.012 (0.036)	-0.152 (0.149)	-0.005 (0.0516)	0.010 (0.036)
Number of other adult females (18 years old and above) in the household	0.958 (0.403)	0.527 (0.405)	-3.480* (2.104)	0.678 (0.597)	-0.563 (0.687)
Number of other adult males (18 years old and above) in the household	-0.330 (0.295)	-0.202 (0.288)	-1.478* (0.892)	-0.254 (0.451)	-0.467 (0.389)
Work distance of oldest adult child (km)	0.058 (0.096)	0.009 (0.091)	0.135 (0.296)	-0.145 (0.175)	0.147 (0.105)
Remittances (yuan)	0.104 (0.143)	0.031 (0.149)	0.522 (0.450)	-0.164 (0.341	-1.186 (0.761)
LRchi2 (Prob >chi2)	134.45 (0.0005)				
Pseudo R2	0.283				

***significant at 1% level ** significant at 5% level *significant at 10% level

In the marketing decision-making category, a higher sharing rule ratio indicates that it is more likely that the wife makes decisions alone relative to her husband making these decisions alone (market crops, market livestock, and contract farming). In the innovation decision-making category, the results show that the sharing rule significantly affects wife making decision alone relative to trying new ideas at home. However, we did not find a statistically significant effect of the sharing rule on making decisions relative to innovation, including adoption of new crop cultivars or decisions related to trying out new ideas on the farm. The sharing rule ratio also has no effect in making decisions on household consumption.

An increase in the sharing rule ratio also predicts the possibility of a more joint decision-making structure, such as the husband and wife making joint decisions or other household members being involved in decision-making, relative to husband making decisions alone. For example, an increase in the sharing rule also suggest that males in a household are more likely to make joint decisions on fertilizer usage, farm equipment purchases, marketing crops, marketing livestock, engaging in contract farming, and trying new ideas at home. It is also more likely for every adult in the household making joint decisions on farm equipment purchases and whether or not to engage in contract farming. *The results for the sharing rule therefore suggest that while a greater share of pooled income going to the wife is likely to increase her engagement in making a number of decisions alone, such increases also suggest greater household engagement in the process as well.* The results answered the first research question in terms of understanding the impact of the sharing rule on intrahousehold decision-making structure.

Labor income effect

The labor income effects are measured through the MPL for both husband and wife. In a competitive labor market, MPL is a measure of labor quality. A better labor quality leads to higher MPL. In our study, since the market wage is observed to be significantly higher than the farm shadow wage, when the MPL value increases, it also suggests that the measure of labor time value shifts from farm work to off-farm work. Wife's MPL predicts negatively on her making decisions alone for some production decisions, such as types of crops to produce, soybean production, farm equipment purchases, and some innovation decisions, such as trying new ideas on the farm or at home. One possible reason is that when off-farm labor income dominates, she spends less time working on farm and in home production, which may reduce her decision-making on farm and home production as a result. But a higher wife's MPL also increases her involvement in making joint decisions with her husband relative to the husband making decisions alone. Significant positive effects are found for husband and wife making joint decisions on marketing crops, marketing livestock, livestock number, and food purchases. A closer look at the husband's MPL impact reveals no surprising results. An increase in husband's MPL predicts a decrease in the wife's making decision alone on food purchases. An increase in his MPL also suggest that it is less likely that the husband and wife make joint decisions on new crop cultivar adoption and livestock feed.

An interesting finding is that the likelihood of adult males making joint decisions as a group increases as a result of an increased MPL for either the wife or husband. Statistically significant impacts on males within the household making joint decisions relative to the husband making decisions alone are found for deciding on type of livestock and livestock feed. An increase in husband's MPL predicts an increase in males within the household making joint decisions on farm equipment purchases. *These findings suggest that when the husband and wife are more engaged in off-farm work, adult sons are more likely to be involved in household decision-making structure increases.* The results also show that a higher wife MPL only influences the joint decision-making of household females as a group in terms of their greater involvement in making joint food consumption decisions. Thus, other females in the household do not appear to become engaged in decision-making regarding the farm or related to innovation, under these conditions.

Work participation effect

The farm work participation behavior of the wife increases her involvement in making decisions in general and the impact is statistically significant on food purchase, food consumption, livestock number and livestock feed. Husband's farm work participation behavior, however, discourages wife's involvement in making decisions on fertilizer and pesticide/herbicide use, in particular. Such results show labor participation in farm work is critical not only for making farm production decisions, but also for consumption, marketing and innovation decisions.

Both the husband's and wife's off-farm work participation behaviors show statistically significant impacts on the farm production decision structure. Husband's off-farm work participation behavior predicts a significant increase in the likelihood of wife making decisions alone in all consumption, production, innovation, and two of three marketing decisions. It also shows husband and wife are more likely to make joint decisions on livestock type, marketing crops, and marketing livestock. A positive effect is found on females as a group making joint decisions on what livestock to keep, fertilizer usage and the marketing of livestock. Wife's off-farm work participation behavior, however, reduces her engagement in decisions (alone) related to livestock numbers and livestock feed.

Further measures of the potential influence of work – i.e., the off-farm work distance variables – reveal no statistically significant effect on the wife making decisions alone, with an increase in distance that the husband needs to travel to his off-farm work. On the contrary, as husband works farther away, it is more likely for wife making decisions alone on fertilizer usage, marketing of crops and livestock declines. It is possible that husbands have more access to the markets or marketing information as their off-farm work distance increases. Statistically significant negative effects are also found for males making joint decisions on farm equipment purchases and new crop cultivar adoption, as the husband works farther away. An increase in wife's working distance, however, predicts negatively on her decision-making on marketing livestock, while this increases 1) the involvement of males making joint decisions on food purchases and new crop cultivar adoption and 2) the involvement of household females making joint decisions on livestock types. *In answering the third research question, the above results suggest that it is less likely for household males making joint decisions on soybean cultivar adoption with an increasing work distance of the husband, but opposite effect is found on an increasing work distance of the wife. The likelihood of the wife making decisions alone was not found to increase with an increase of the husband's work distance, in general.*

The comparison of husband and wife's home production participation behaviors also yields some interesting results. Wife's home production participation is found to reduce her decision involvement on crop types, soybean production, livestock number, pesticide/herbicide usage, marketing crops, and contract farming. Husband's home production participation, however, increases the chance that both husband and wife make decisions jointly on seven out of the fifteen decisions analyzed here: food purchase, food consumption, livestock feed, fertilizer usage, marketing livestock, new crop cultivars adoption, and trying new ideas on the farm. *The result suggests that husband participation in home production is a good indication of husband and wife's joint decision-making structure relative to a husband-dominant household decision-*

making structure. This result answers the second research question and confirms that household members' time spent on home production alters their decision engagement and likely power relative to farm production activities.

Characteristic factors

The age difference between husband and wife was not found to have a statistically significant impact on the intrahousehold decision making structure, in general. The positive schooling difference between husband and wife, however, weakens the wife's engagement in decision-making in almost all but the consumption decision category. Negative impacts are especially found for the wife making decisions alone on fertilizer usage, pesticide/herbicide usage, engaging in contract farming, trying new ideas on the farm, trying new ideas at home. *The results suggest that when the difference in schooling is large between the husband and wife, she is much less likely (as compared to couples with more balanced schooling attainment between them) to engage in making decisions alone on farm production, marketing and innovations.*

Influence of other household members

The influence of other adult household members is measured by gender, work distance, and remittances. A higher composition of females within a household shows that it is more likely for the wife (relative to husband) making decisions alone on food purchases, while less likely for the wife making decisions alone on fertilizer usage, pesticide/herbicide usage, marketing crops, marketing livestock, trying new ideas on the farm, and trying new ideas at home. A greater number of females present in a household also reduces the chance that males in the household make joint decisions as a group. The affected decisions are food purchases, food consumption, soybean production, livestock numbers, livestock feed, farm equipment purchases, pesticide/herbicide usage, marketing crops, marketing livestock and new crop cultivars adoption.

A greater number of males present in a household does not appear to contribute to a higher likelihood of males making joint decisions as a group, either. Negative impacts are found for decisions including food purchases, food consumption, soybean production, livestock numbers, livestock feed, fertilizer usage, pesticides/herbicides usage, marketing crops, contract farming, new crop cultivars adoption, and trying new ideas on the farm.

Finally, the labor migration effects from other household members are examined by including both work distance and remittance factors. Since there may be multiple adult children present in a household, the oldest child's work distance is used to predict possible effects on household joint decision-making structure. Interestingly, in general, the out-migration distance variable generally is not statistically significant, showing no influence in most cases. However, the estimation results for remittances suggest that the greater the amount of remittances children submit to a household, *the more likely they are to be engaged in household decision-making processes.* Significant positive effects are found on males make joint decisions relative to the husband making decisions alone regarding: soybean production, farm equipment purchases, marketing crops, engaging in contact farm, new crop cultivars adoption, and trying new ideas at home.

Unfortunately, our data do not show what percentage of males contributes to the remittance transfer. *Nevertheless, such results reveal that off-farm migration can have profound impacts not only on labor time allocation, but also on household decision-making structure. The financial support from those engaging in off-farm migration appears to provide them with a voice in making a broad array of decisions. That is, it is unlikely that out-migration results in only those at the origin making decisions that are likely to have broad implications in a multi-generational sense and for China's future.*

5.4. Concluding Remarks

In this study, labor time allocation and income sharing decisions of rural farm households in south China are analyzed in a collective modeling framework. The decentralized household utility maximization problem becomes individual members' joint efforts to pursue personal welfare while being influenced by the other household members' production activities. For rural farm households in China, not only are the on-farm production activities heavily affected by off-farm migration behaviors, but also the imperfect labor market creates a binding constraint on the off-farm labor supply. As a result, the market wages no longer provide the proper measure for the opportunity cost of on-farm labor supply. By taking account of the heterogeneity that exists among individuals, the value of labor time is associated with the work categories. The MPL of on-farm production is estimated based on Jacoby's shadow wage method, which is essential to provide appropriate estimation of labor supply functions. We find that husband's labor supply is significantly affected by his own and his wife's MPL. The nonlabor income also has a significant effect on his labor supply. Comparing to husbands, wives labor supply behaviors do not change significantly with the marginal product of labor or nonlabor income. Only the joint MPL is found to have a major impact on her labor supply. Being less responsive in labor supply, the wives are found to be more altruistic than the husbands in transferring nonlabor income to the spouse when her MPL increases. The migrants' sex ratio is found to significantly influence the transfer of nonlabor income.

The sharing rule is derived from the labor supply functions, and its impact is further examined with on-farm, off-farm, and home production participation behaviors in predicting intrahousehold decision-making structure. The maximum likelihood results suggest that an increase in her share of nonlabor income significantly influences the wife making decisions alone over marketing and multiple innovation and production decisions, but not all. This result provides empirical support that transferring nonlabor income from husband to wife will increase wife's engagement in the household decision-making processes, but the impact is limited.

Further, when the wife spends more time working in the wage market, her MPL is higher but her involvement in farm production declines, which is likely to reduce her engagement in decision-making relative to making farm-related decisions. But a higher MPL increases her involvement in making joint decisions with her husband relative to him making decisions alone. The adult males are more likely to be involved in the household decision-making structure with an increase of either husband or wife's MPL.

Husband's home production participation results in a more balanced husband-wife joint decision-making structure relative to a husband-dominant household decision-making structure relative to farm production activities. Husband's off-farm participation behavior has an impact on farm production decision-making structure, and especially increases wife's chance of making decisions alone or making joint decisions with her husband.

Household males as a group are less likely to make joint decisions on farm production when the husband's off-farm working distance increases. However, it is inconclusive for the wife's engagement in decision-making process when the husband works farther from home. Remittances are found to increase the involvement of household males as a group making joint decisions. And the greater the schooling difference between husband and wife, the less likely she makes decisions alone relative to her husband making them.

Chapter 6

SIMULATION WITH AGENT BASED MODELING

6.1 Repeated Game Theoretic Approach

The advantage of having first-hand data is that the dataset more closely reflects reality in the survey region. Researchers have more confidence in the validity of the research. At the same time, a disadvantage of a baseline survey is that it provides no dynamic impacts — no changes over time that may be attributable to an initial change, such as the introduction of a new technology. Some effects (i.e., after a new agricultural technology is introduced) are only measurable with continuous efforts in collecting data and observing changes over time. It is expensive in practice. Given this and at this stage in the research, we rely on a simulation method that demonstrates the implicit interactions of household labor-hiring and land-leasing behaviors.

Agent-based modeling or ABM is used as a more dynamic and interactive modeling framework, and will be employed here. Agents are defined as households with the ability to learn from each other. Events are carried out as programming steps, which correspond to agents' behaviors in the decision-making process. The modeling system couples off-farm work and labor and land use decisions at the household level. As the problem becomes more realistic, it evolves into a complex system containing the process of learning and trading information among agents, which is generally difficult to model econometrically. The feasibility of study interactions is one of the preferred characteristics of using agent-based models.

We are interested in agents' interactive and decision-making processes. Assume a farm household makes the off-farm work decision first, and then faces the options of leasing land or hiring labor. A conceptual diagram of agents' decision making is specified in figure 6.1.

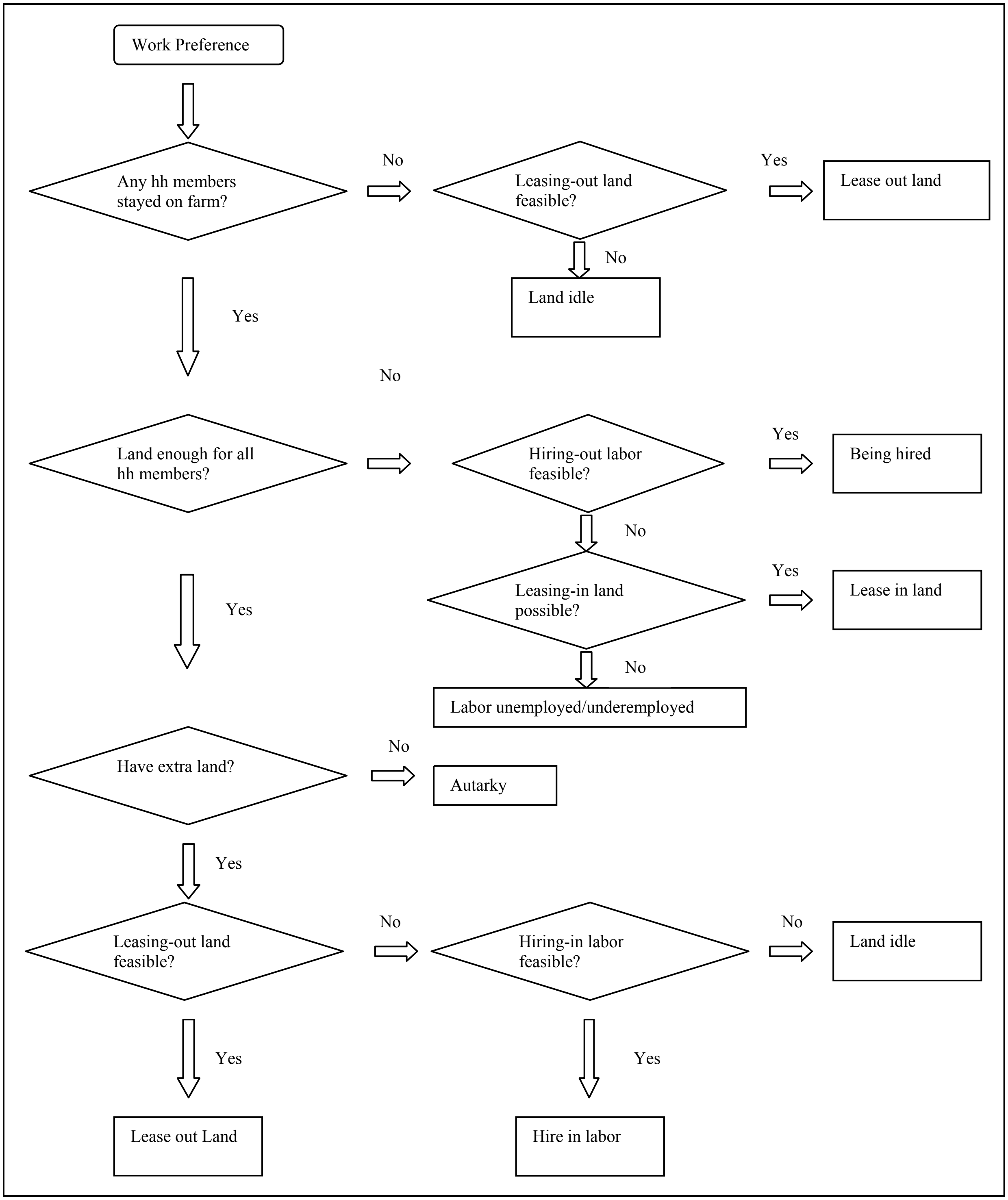


Figure 6.1 Flow diagram for household (hh) land-leasing and labor-hiring decision-making

As outlined in chapter 3, an agent's own payoff maximization strategy with a prediction of the other agent's chosen strategy will lead to two pure Nash equilibria: land-leasing agreement or labor-hiring agreement. The land-leasing agreement is payoff dominant, analogous to hunting deer, while the labor-hiring agreement is risk dominant, analogous to hunting hare. In the former case, agents coordinate and trust each other in hope of reaching an agreement, which provides both agents the best payoffs to obtain Pareto optimality and reach social optimality collectively. In the latter case, agents have doubts about each other's commitment to cooperative efforts. An agent will choose to deviate from the best payoff option to avoid facing the consequence, if the opponent defects in the land agreement.

Often the risk dominant strategy is chosen by both agents for a one-period game, since neither agent is willing to risk receiving zero payoffs, if they believe that the opponent may defect from the payoff dominant strategy. But in a repeated game, the agents' risk-avoiding strategy may not be the optimal approach. A high degree of coordination and cooperation can be found on many occasions when trust emerges between agents who are capable of learning from experience and from each other. In addition, "social norms" or rules may trigger punishment of agents who deviate from the cooperative strategy, and the social optimum is thus reached. In this case, a tit-for-tat (TFT) strategy may be adopted. The TFT strategy triggers retaliation from an agent when defective behaviors are observed from the opponent. The quick forgiveness condition of TFT assures that once cooperative behavior is observed from the opponent, an agent will switch to cooperate in the next game round (Axelrod, 1984).

In repeated games, agents can imitate the best strategy. Since the results from previous interactions are observable to agents, they assess their own payoff and compare with the payoff received by their opponents. During this process, strategies are reevaluated and interactions are expected to lead to adoption of the most successful strategy.

6.2 Multi-Tasking ABM

The objective in a broad sense is to simulate the farm household labor-hiring and land leasing decision-making process under the potential impact of 1) off-farm labor market development, 2) new soybean cultivar adoption, and 3) land policy change. In China, traditional cropping systems have maintained productivity over many centuries through labor-intensive nutrient management by a large and predominantly rural population[32]. In recent years, however, increasing population pressures, urbanization, and reliance upon chemical fertilizers -- especially reduced nitrogen (N) fertilizer that can cause soil acidification and accelerate organic matter oxidation - raise serious concerns about the continued viability of both traditional and contemporary cropping systems in the region (Ash and Edmonds, 1998; Wong et al., 2002). Legumes, such as soybeans, are important in fixing N, thereby improving soil fertility and decreasing the need for N fertilizer. Besides the beneficial effects on soil productivity, legumes also have unique importance to human nutrition; they are a primary source of dietary iron, vitamin A and are a concentrated source of vegetable protein, thus an important complement to cereals and starches in the diets of the rural and urban poor in developing countries (Messina, 1999; Iqbal et al., 2006). In recent years, a rising world demand for soybeans for bio-energy production and animal feed has been observed, further emphasizing the importance of this crop.

In chapter 5, soybean production and new soybean cultivar adoption decisions were analyzed econometrically to identify the intrahousehold decision-making structure relative to each decision. In the current stage, we simulate the *ex post* effects of releasing new soybean

[32] Discussion in this section is based on project team proposal to McKnight Foundation.

cultivars in villages on individual household participation in labor and land markets. The feedback effect of new technology adoption may alter household decisions regarding labor and land distribution and market trading behaviors (Otsuka et al., 1992). Increased soybean productivity hopefully will turn into higher farm profit, which is likely to affect the relative importance of on-farm verses off-farm production and influence household labor and land resource allocation.

Figure 6.2 highlights the multilayer interrelationships graphically. Each layer in the multilayer structure system demonstrates a particular problem. In the first layer, the focus is on adoption, with the successful adoption of new soybean cultivars increasing soybean production scale locally. Whether the increased soybean production leads to a reduction of land use for other crops will depend on farm market conditions and demand for other crops, but the simulation here focuses solely on soybeans. Assuming that most land in south China is already under intensive cultivation, if the steadily increasing soybean demand ensures higher profitability of growing new P-efficient soybeans cultivars and requires less labor input, the simulation process will help us to explore increasing farm profitability impact on farm land market formation in villages.

The second layer involves agents' interactions and decision-making rules. The dominant factor here is labor resource allocation. As emphasized throughout the dissertation, farm households in rural China are characterized by high rates of the working-age population migrating for off-farm jobs. Household members make choices of participating in on-farm and off-farm production, guided by market conditions. Among households, agents negotiate on land-leasing or labor-hiring. Household decisions on labor and land resource allocation will be simulated in this chapter with and without the new soybean cultivars adoption.

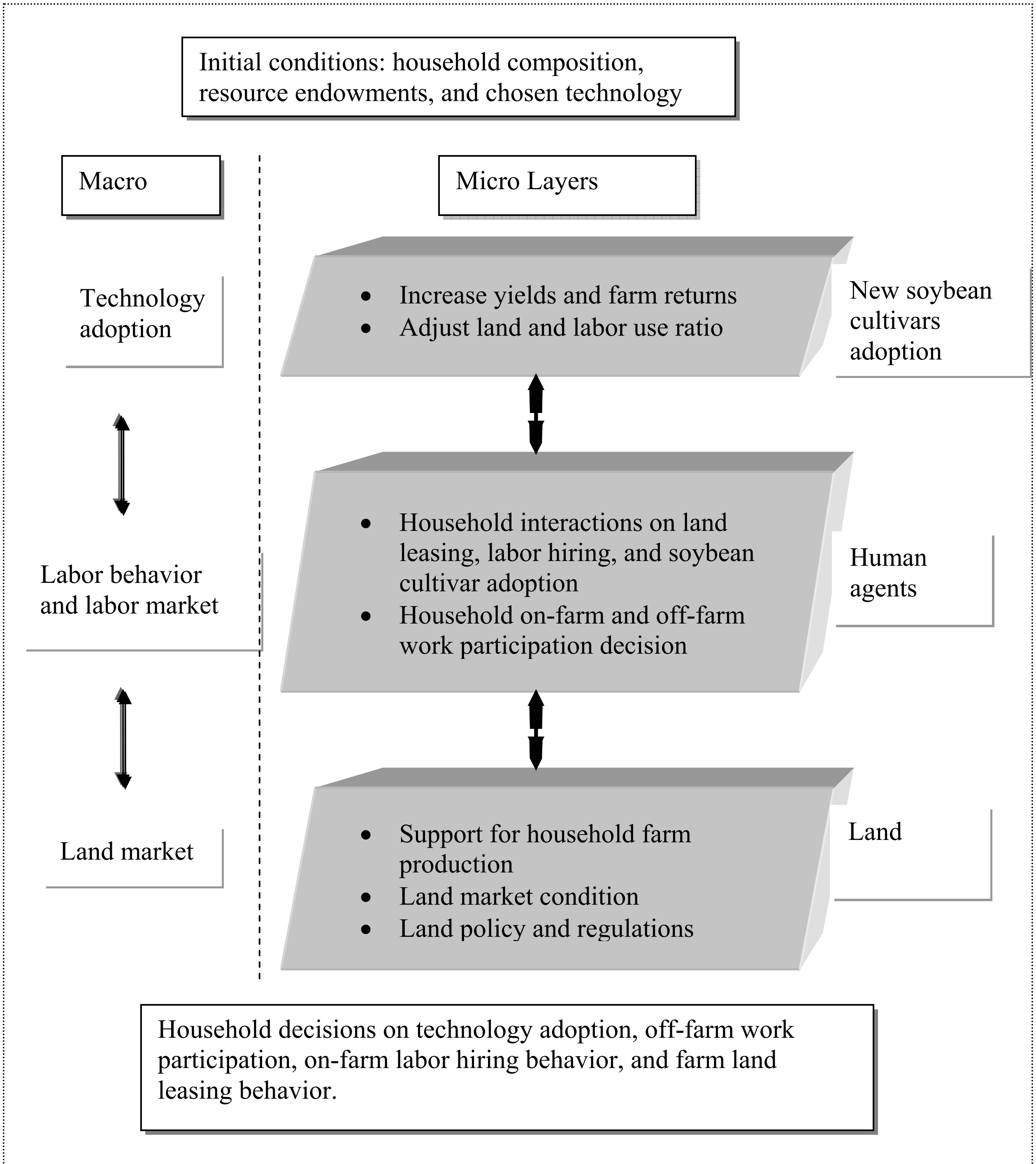


Figure 6.2 New soybean cultivar adoption, household labor supply and land market development

In the final layer, we emphasize the emerging land use right transfer. Deininger (2003a) believed that transferable land rights make it less costly for rural residents to take jobs in the non-farm economy, which is likely to strengthen the off-farm sector. The formation of land-leasing markets is expected to be affected by labor production behaviors and new soybean cultivar adoption behaviors. In addition, changes in land policy and regulations, especially as concerns land tenure security, are expected to greatly affect land transfer among households.

As explained earlier, the land-leasing market is underdeveloped in the regions where *the ex ante* survey was conducted. To illustrate the interactions among off-farm work participation, farm labor-hiring behavior, and farm land-leasing behavior, relative ratio estimates are used in the payoff matrix considering that local land rental data are not available. The simulation results are analyzed based on the artificial data and can be further validated when survey or census data become available. Our focus on specific scenario construction is to reach the following specific research objectives:

1. To identify the minimum number of initial agents required for land-leasing commitment for a land-leasing market to develop under various scenarios.
2. To identify the land-leasing market speed of development by varying the initial agent compositions.
3. To measure the off-farm labor market impact on farm labor-hiring and land-leasing markets.
4. To measure the impact of new soybean cultivar diffusion on farm labor-hiring and land-leasing markets.
5. To incorporate potential policies on land-leasing markets and measure the effects.

The Recursive Porous Agent Simulation Toolkit (Repast) is employed to simulate the interactions of agents and their emergent collective behaviors, assuming that each agent makes rational decisions based on potential payoffs associated with a chosen strategy. Several additional assumptions are specified to provide guidelines for agent behavior. It is critical to have reasonable assumptions allowing a simplified model structure and, at the same time, will not lose the generality in which the model applies (Moss, 2008). Basic assumptions are:

1. *One-on-one pair-wise interaction between agents.*
2. *Agents have abilities to learn from experience and from each other.*
3. *Agents are located on fixed grids. One agent only interacts with four neighbors, who are directly above, below, to the right and to the left of the agent.*
4. *Agents are locked into their strategy in one year (one game round) with a switching strategy allowed in the next year.*
5. *Payoffs for land-leasing are greater than labor-hiring.*
6. *The payoff structure is symmetric.*
7. *In the beginning of a year, one neighbor is chosen randomly from the entire agent population and three neighbors remain the same.*
8. *Labor remaining in the villages can participate in labor-hiring for farm production or for off-farm work in surrounding areas; the off-farm labor return is greater than or equal to the on-farm labor return, depending on labor market conditions.*

Finally, to better describe real world situations, the following assumptions are introduced, depending on the simulation scenario:

1. *Soybeans are one of the major crops produced. New soybean cultivars feature higher productivity with less labor input needed. A higher return on land input is expected.*

2. *Imperfect labor market conditions may apply. A payoff discrepancy exists between the off-farm wage and on-farm labor hiring costs under such a condition.*

In absence of detailed data on land rents and labor hiring cost, we simplify the payoffs with the following payoff matrix:

Household 2

		land	labor
Household 1	land	A, a	B, c
	labor	C, b	D, d

with A>C≥D>B and a>c≥d>b; the strategy pairs (land, land) and (labor, labor) are pure strategy equilibria. Five simulation scenarios (with parameter variations within scenarios) are summarized as follows:

Scena-rios	Payoff values A=a, B=b, C=c, D=d				Agents ratio in chosen strategies: Land-leasing vs. labor-hiring	Scenario conditions
1	3	0	1	1	Ranging from 1:9 to 1:1	Perfect labor market conditions
2	3	0	2	1	Ranging from 1:9 to 9:41	Imperfect labor market conditions
	5	0	2-5	1	Fixed at 1:5	
3	5-20	0	2	1	Fixed at 1:9	New technology adoption
4	5	0	2	1	Fixed at 1:1:16 for land-leasing without TFT, land-leasing with TFT, and labor-hiring.	Introduce land policy reform with imperfect labor market conditions
5	5	0	5-7	1	Fixed at 1:1:16 for land-leasing without TFT, land-leasing with TFT, and labor-hiring.	Introduce land policy reform with increasing wage gap in labor return between on-farm and off-farm work

Before the detailed simulation analysis, it is necessary to explain how we understand market development and functioning. By means of land market development, we refer to the number of agents engaged in land-leasing market growth and reaching a stable convergence. There is no strict condition on the number of agents required for a land-leasing market to develop or function well. For the ABM simulation, the sample agent population is composed of 256[33] agents located in 16-by-16 grids, with one agent occupying each grid cell; this arrangement makes the simulation process simpler by using a ratio number for both agent types. But notice that by increasing the grid size, the agent sample population grows rapidly. The same relative agent ratio means completely different absolute agent number. For example, a 50 percent of sample population in a 16-by-16 grid has about the same number of agents (128 agents) as a 10 percent sample population in a 35-by-35 grid and a 20 percent sample population in a 25-by-25 grid. So if we force a condition of well-functioning market as a 50 percent sample population engaging in the market in the current 16-by-16 grid, then this compares to a 10 percent sample population to engage in the market to reach the same number of agents in a 35-by-35 grid.

6.3 Simulation Results

6.3.1 No Triggering Strategy Included

Agents have two strategies available to choose from: aiming at leasing land and aiming at in hiring labor. At the beginning of a new game round, each agent will switch strategy to an opponent's (neighbor's) strategy if the opponent has an average cumulative payoff strictly larger than his own. Otherwise, an agent will continue his own strategy. Notice that there is no triggering strategy applied (i.e., no TFT). This assumption simplifies an agent's strategy set, while provides a clearer picture of how a high level of coordination behaviors develops and dominates the risk-avoiding behaviors over time, thus reaching social optimality collectively.

[33] According to 2006 China agricultural census data, China has about 637,011 villages and 200,160,000 farm households in total and the average village size is 314 households. Our design of a 16-by-16 grid generates 256 agents in the sample, which is a realistic number for an average village size.

Without the triggering strategy designed in the system, the high degree of tolerance or forgiveness among agents also reflects certain reality factors in rural China. As we discussed in the literature review section, farm land and farm housing sites belong to farm collectives of villages. Individual households are entitled to user rights only, based on previous land allocation decisions made by the village council or village leaders. Land leasing is not completely legitimate and restrictions vary at the village level (Krusekopf, 2002). Land user rights are traded based on individual's will, and the consequences are generally not protected by either land law or village council. During the land leasing agreement negotiation procedure, either agent's incentive to deviate from reaching the final agreement is comprehended by the opponent, even though both agents understand that reaching such agreement will lead to better payoffs than deviating and choosing other strategy options.

Scenario 1: On-farm labor hiring cost equals to off-farm wage in surrounding areas

Let A=a=3, B=b=0, and C=c=D=d=1 in the payoff matrix. We define agents as receiving triple the amount of payoffs from leasing land than for hiring labor. By changing the percentage of agents committed to both land-leasing and labor-hiring, we identify the minimum initial amount of land-leasing agents required for a land market to develop. Figures 6.3.1a-6.3.1b show varying agents' initial ratio in choosing the strategy for a land market to develop. With years shown on the x-axis, and number of agents indicated on the y-axis, the simulation traces the changes in numbers of land-leasing agents (red line) and labor-hiring agents (black line) by year. The simulation results suggest that the land-leasing agents will switch to a labor-hiring strategy when the land-leasing agent population size is below a certain percentage (fig. 6.3.1a).

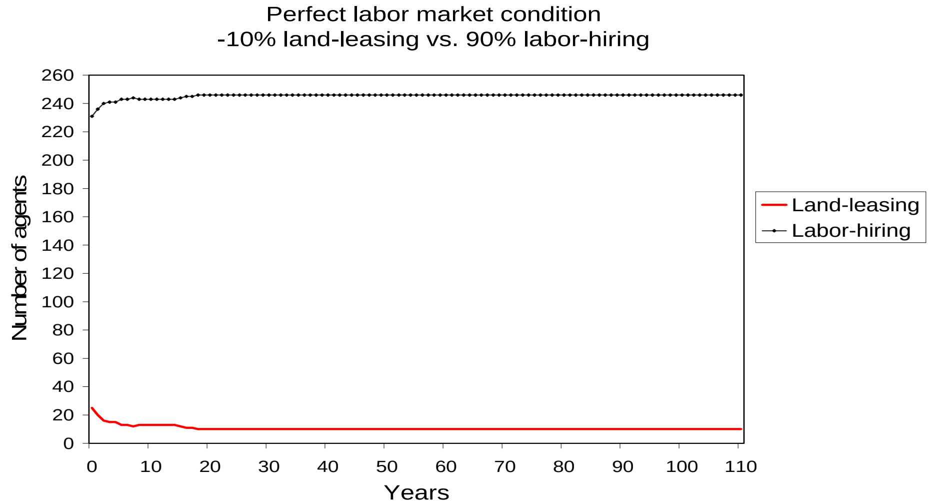


Figure 6.3.1a Perfect labor market condition: 10 percent land-leasing agents vs. 90 percent labor-hiring agents

Under the current payoff structure, the land-leasing strategy will not expand and become more successful than the labor-hiring strategy until about 17 percent agents start off choosing the land-leasing strategy. This scenario is depicted in figure 6.3.1b. As shown in figure 6.3.1b, the dominance of the land-leasing strategy leads to a stable convergence.

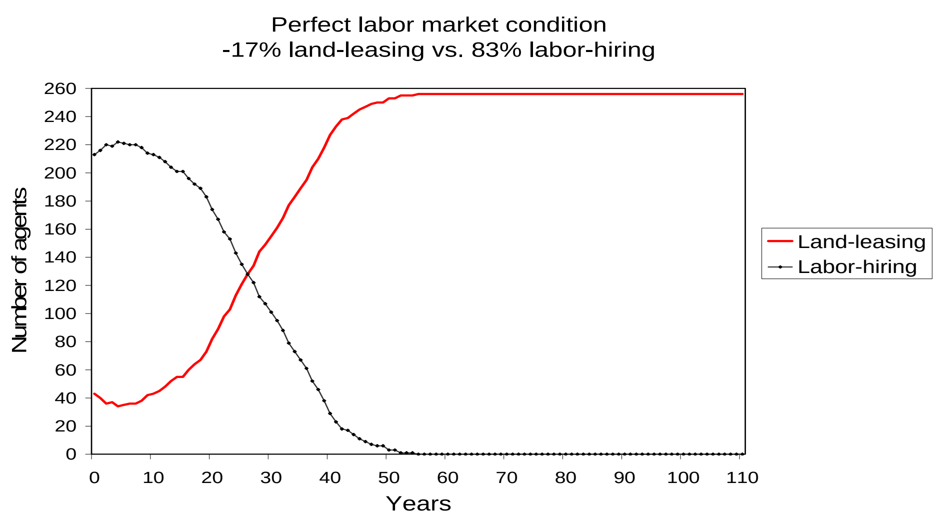


Figure 6.3.1b Perfect labor market condition: 17 percent land-leasing agents vs. 83 percent labor-hiring agents

The speed of convergence is measured through continuous changes in the ratio of both agent types. The initial population of land-leasing agent is 17% and expands every year (game round). In close to 26 years, the land-leasing strategy became dominant over the labor-hiring strategy, which indicates the time length needed for the formation of a well functioning land-leasing market. As the initial population of land-leasing agent continues to grow, the counts of game rounds (years) for land-leasing strategy to dominate become shorter and shorter, which indicates a more rapid land market formation procedure.

Figure 6.3.1.c shows the relationship between an increase in initial land-leasing agent population size and predicted years needed for the land-leasing strategy to become dominant. The land-leasing and labor-hiring ratio was bounded between 17/83 and 50/50. Any ratio number below 17/83 will not lead to a dominant land-leasing strategy. With the initial land-leasing agent's ratio on the x-axis, for every 5, 10 and 15 years, changes in the number of land-leasing agents are recorded as an increment of the land-leasing and labor hiring ratio (first y-axis). The minimum years needed for the number of land-leasing agents to exceed the labor-hiring agents are recorded by changes in the initial land-leasing agent's ratio (second y-axis). When the number of agents engaged in the land-leasing strategy dominates and is stabilized, the land-leasing market is developed. The result shows that it takes more than 25 years for a land-leasing market to stabilize when the initial land-leasing agent counts are less than 18 percent of the sample population. As we increase the number of agents committed to a land-leasing strategy to around 26%, the land market stabilizes within 10 years. When the number of agents committed to a land-leasing strategy reaches around 35%, the land market stabilizes within 5 years.

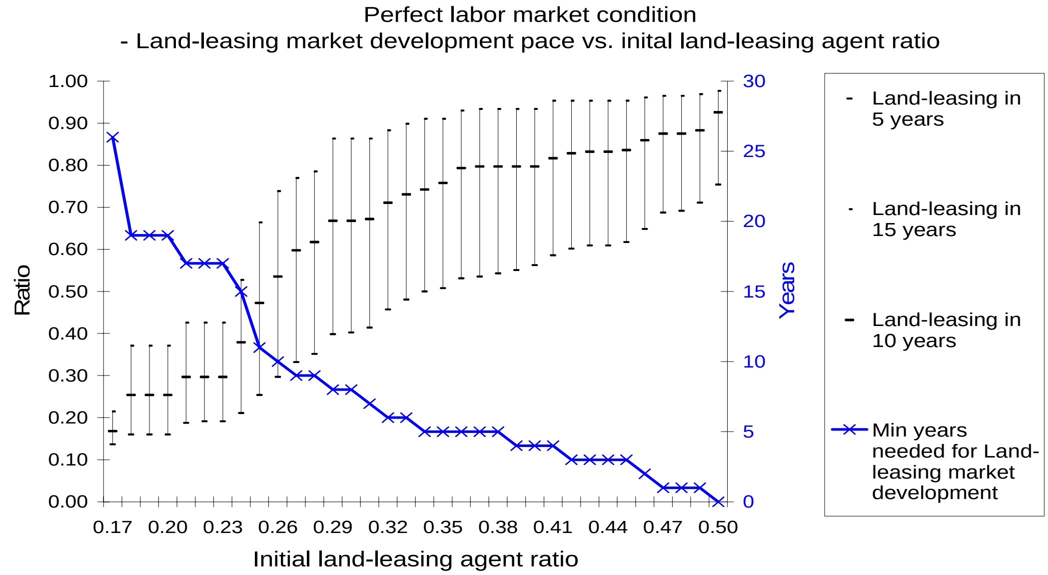


Figure 6.3.1c Perfect labor market condition: Changing the initial households' strategy ratio to predict land-leasing market development pace

Scenario 2: Off-farm wage in surrounding areas exceeds on-farm labor-hiring payoff

Let A=a≥C=c, B=b=0 and C=c>D=d=1 in the payoff matrix. Firstly, we identify the initial population size of land-leasing agents needed for the land-leasing strategy to dominate under payoffs of A=a=3, B=b=0, C=c=2, and D=d=1. That is, the off-farm wage in surrounding areas doubles the payoffs received through a labor-hiring strategy. Figure 6.3.2a shows the initial scenario with 10% land-leasing and 90% labor-hiring, with figure 6.3.2b indicating the situation where there are enough agents pursuing a land-leasing strategy to achieve change under Scenario 2. Figures 6.3.2a and 6.3.2b show that the land-leasing agent population size must increase from about 10 percent to 18 percent. The results are similar to Scenario 1 when about 18 percent of agents initially pursued a land-leasing strategy, and where the strategy expands and becomes more successful than the labor-hiring strategy over time. The difference between those two scenarios is that, as shown in figures 6.3.1b and 6.3.2b, *the time length needed for a land-leasing* *strategy to become dominant is much longer in Scenario 2.* This suggests that there will be delayed land market development due to changes in off-farm labor market conditions.

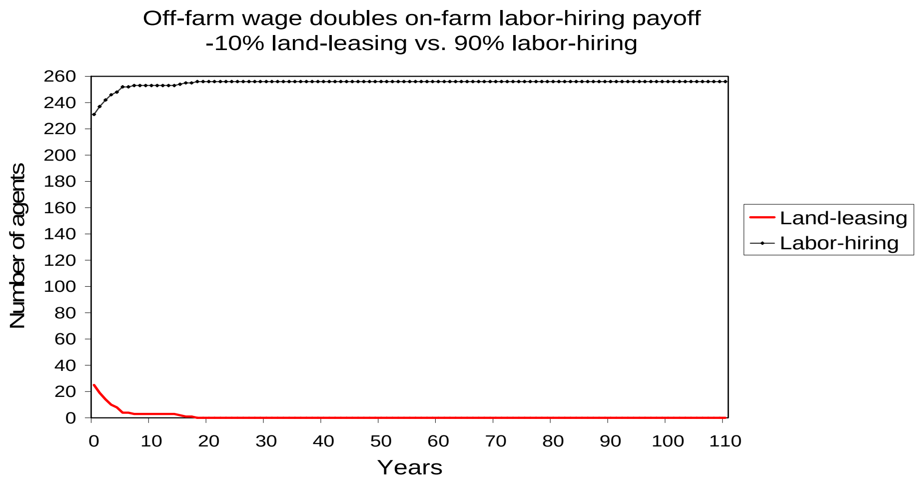


Figure 6.3.2a Imperfect labor market condition: off-farm wage doubles on-farm labor-hiring payoff- 10 percent land-leasing agents vs. 90 percent labor-hiring agents

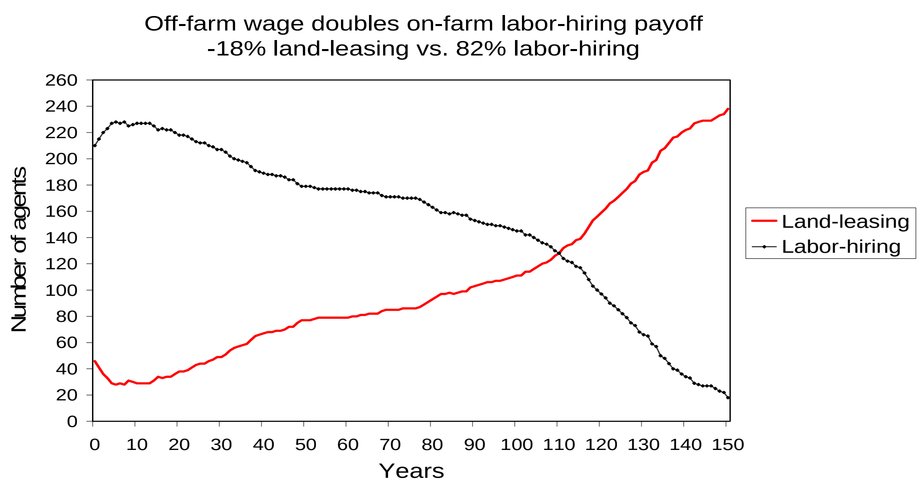


Figure 6.3.2b Imperfect labor market condition: off-farm wage doubles on-farm labor-hiring payoff- 18 percent land-leasing agents vs. 82 percent labor-hiring agents

To further assess the off-farm labor market influence on both on-farm labor-hiring and land-leasing market development, we further alter the matrix payoff structure as $A=a=5 \geq C=c \geq D=d=1$, and $B=b=0$. The initial agent ratio is fixed at 20 percent for the land-leasing strategy and 80 percent for the labor-hiring strategy. Changing the ratio between off-farm wage and on-farm labor-hiring payoffs, the results are graphed in figure 6.3.2c with pairs of colored lines representing pairs of land-leasing and labor-hiring strategies for the same matrix payoff structure.

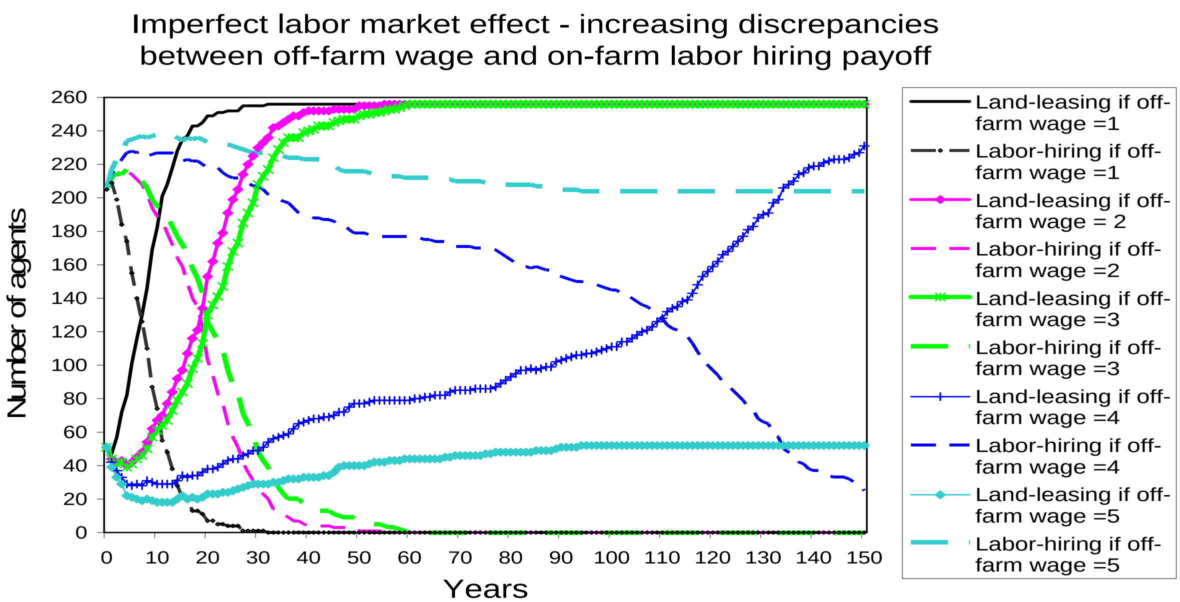


Figure 6.3.2c Imperfect labor market condition: increasing discrepancies between off-farm wage and on-farm labor hiring payoff – 20 percent land-leasing agents vs. 80 percent labor-hiring agents.

With larger discrepancies between the off-farm wage and on-farm labor-hiring payoff, the time needed for the land-leasing market to develop increases. When the off-farm wage equals the land-leasing payoff, agents choose either the land-leasing or labor-hiring strategy but the dominance of the land-leasing strategy does not emerge over time. Intuitively, under imperfect off-farm labor market conditions, the farm shadow wage deviates from the off-farm wage. When the difference becomes so large that farm labor cost is minimal, the return to farm production mainly accrues to the land owner. Households with extra labor can be expected to actively search for off-farm work opportunities since the payoff is the same as leasing-in land but with no investment risks involved as in leasing-in land. Households with extra land would prefer to keep the land by hiring in labor working on the land.

Scenario 3: Higher returns on land results from adoption of new soybean cultivars

Scenario 3 is built upon Scenario 2 in that the off-farm wage in surrounding areas exceeds the on-farm labor hiring cost. Let $A=a \geq C=c$, $B=b=0$, $C=c=2$, and $D=d=1$ in the payoff matrix. The land-leasing payoff is gradually increased to illustrate the impact of new soybean cultivars' diffusion on both labor-hiring and land-leasing market development. Farm households seek new technologies that increase profitability by raising yields and/or reducing input usage. Their behavioral change response to the intensity of land use and labor use are closely related to conditions in those two factor markets.

In general, land is considered as a scarce resource limiting agricultural production in China. China has 7 percent of the world arable land resources, which averages only 0.08 ha per capita[34] in land resource. According to FAO data, China is the world's top soybean importing country in spite of a constant increasing of domestic soybean production scale since 2000. Soybean producer price ranks highest among five other major crops (maize, rice, sugar cane and sugar products, sweet potatoes, and soybeans) produced in China (see data chapter for details). Since soybean production is also considered as a less labor-intensive activity, the adoption of new soybean cultivars is expected to increase the demand for land.

Initially, we fix 10 percent land-leasing agents versus 90 percent labor-hiring agents for Scenario 3. Based on the previous analyses, the land-leasing strategy will not emerge as a dominant strategy with such a low initial ratio in the sample population. However, as the payoff from the land-leasing strategy is increased, convergence occurs when the payoff of land-leasing

[34] See Smil (1999)

is six times greater than the payoff to the labor-hiring strategy. Figures 6.3.3a and 6.3.3b show changes that occur as the land-leasing payoff increases from five to six times that of the labor-hiring payoff. Figure 6.3.3c then illustrates the speed of attaining a dominant land-leasing strategy over the labor-hiring strategy, relative to the payoff difference. The initial land-leasing agent ratio remains at 10/90. The simulation result shows that in spite of increasing payoff differences between land-leasing and labor-hiring, the years needed for land-leasing strategy to dominate will not keep shortening. When the payoffs to land-leasing are eight times or more, the time needed for the land-leasing strategy to dominate remains at 11 years. From a game theory point of view, simply increasing the payoff for the payoff dominant strategy will not change the fact that players may still choose the risk dominant strategy to avoid even larger potential loss.

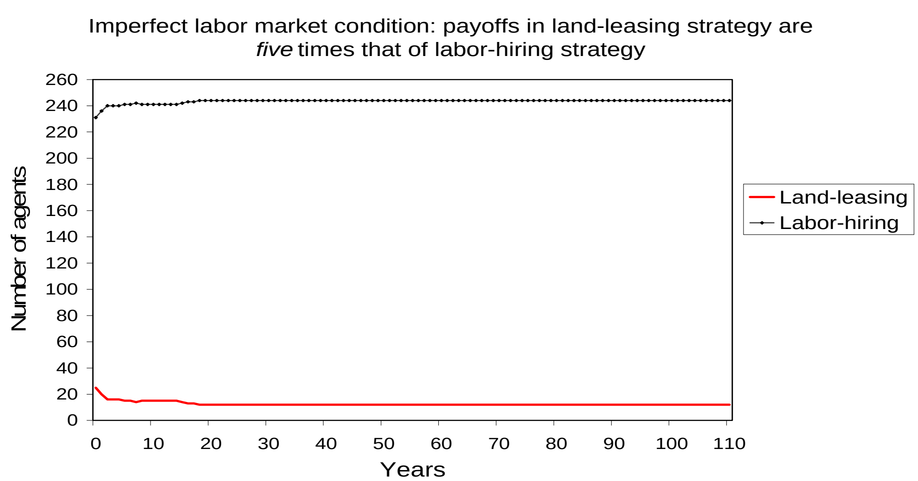


Figure 6.3.3a Under imperfect labor market condition: 10 percent land-leasing agents vs. 90 percent labor-hiring agents and payoffs in land-leasing strategy five times that of labor-hiring strategy

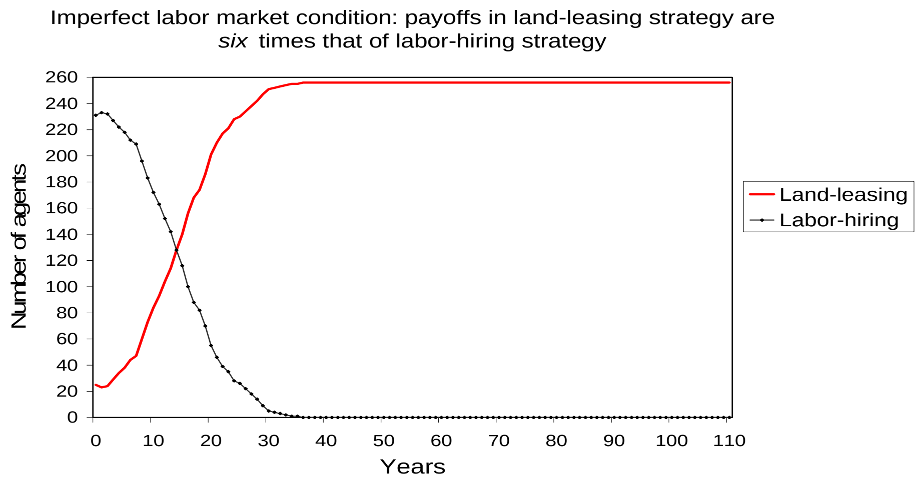


Figure 6.3.3b Under imperfect labor market condition: 10 percent land-leasing agents vs. 90 percent labor-hiring agents and payoffs in land-leasing strategy six times of labor-hiring strategy

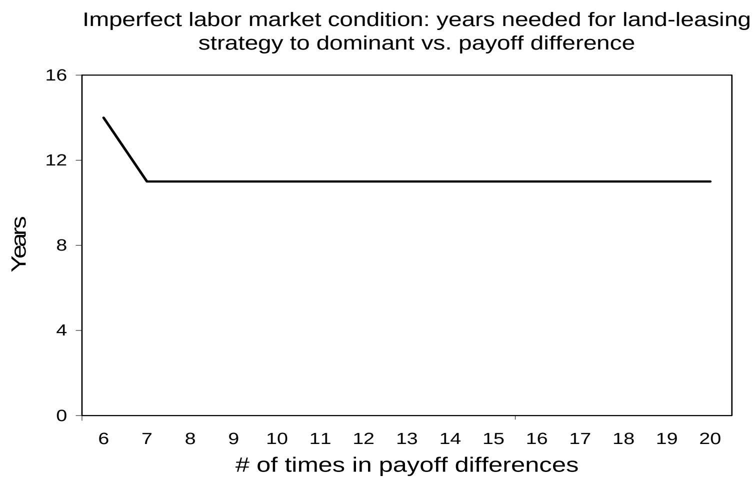


Figure 6.3.3b Under imperfect labor market condition: years needed for land-leasing strategy to dominate with continuously increasing land-leasing payoffs

6.3.2 Triggering Strategy Introduced

With the growth of Chinese economy, many reforms have taken place in the rural areas (Lin, 1992; Yang, 2004) As an example, land policy has been gradually modified from prohibiting farm land leasing to encouraging leasing farm land user rights to a greater extent, while also encouraging rural labor mobility (Yang, 1997; Yao, 2000). Although implementation of a pro-free trade of land policy has not been an easy task at the local village level, entrustment arrangements are beginning to emerge among households within villages. Especially in regions characterized by high rates of the working-age population taking off-farm jobs, the village council sometimes rents out village land which has not been allocated to individual households or can even serve as an agent to help households in land rental transactions (Krusekopf, 2002). As more and more farm households consider participating in the land leasing market, some "social norm" is expected to gradually become established. "Social norms" serve to protect the common interests of households on both sides of the land market transaction by reducing the amount of "bad transactions" and lowering the chance that some households are not fully committed to leasing land.

To incorporate the potential for community reaction to agent non-compliance with social norms, we bring in a tit-for-tat (TFT) strategy to the agents' option set. TFT has proven to be a highly effective strategy to retaliate against a defective behavior from the opponent (Axelrod, 1984). A TFT strategy player will cooperate initially to guarantee that no defective behavior will be initiated without first observing the defective behavior from the opponent from a previous game round.

Scenario 4: Simple TFT effects

To illustrate the triggering effect, we allow half of the land-leasing agents in Scenario 3 to choose a TFT strategy and compare the result with Figure 6.3.3a. Figure 6.3.3a assumes imperfect labor market conditions, a 90 percent sample population as labor-hiring agents and payoffs from the land-leasing strategy five times that of the labor-hiring strategy. As shown previously, such conditions are not sufficient to allow the land-leasing strategy to grow and expand. However, by assigning half of the 10 percent land-leasing agents a TFT strategy (5 percent of land-leasing agents choose TFT strategy, while the other 5 percent of agents do not), the convergence for land-leasing emerges. Figure 6.3.4 shows this effect.

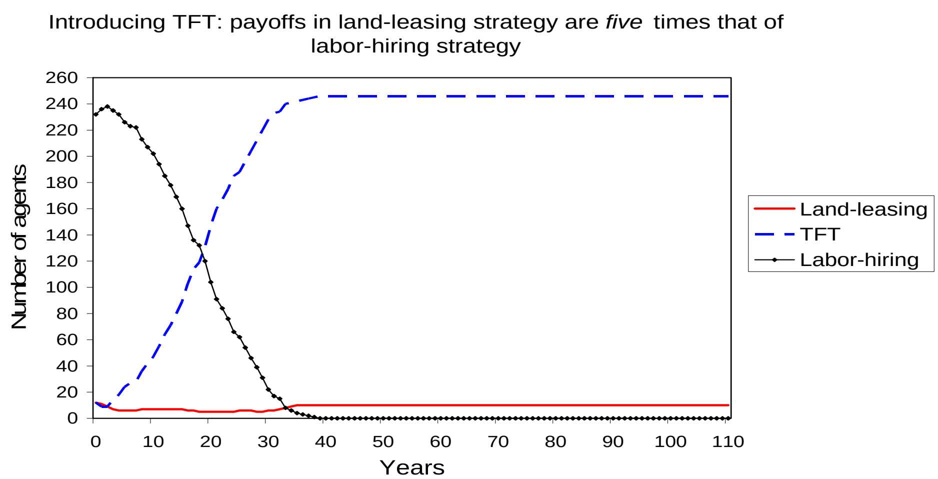


Figure 6.3.4 Under imperfect labor market condition: 5 percent land-leasing agents, 5 percent TFT agents, and 90 percent labor-hiring agents with payoffs in land-leasing strategy five times that of labor-hiring strategy

Scenario 5: TFT effects on increasing discrepancies between off-farm wage and on-farm labor-hiring payoff

Under Scenario 2, the discrepancy between the off-farm and on-farm wage hampered the formation of a land-leasing market. Under Scenario 5, we fix the sample population initially choosing the TFT strategy to five percent. By enlarging the potential payoff difference between off-farm and on-farm production, we record the results in figures 6.3.5a and 6.3.5b. Comparing with figure 6.3.4a for the previous scenario, the graphs show that a more robust land-leasing market is emerging, with convergence occurring in spite of the labor market. The results confirm the importance of land policy implementation in the local villages. By introducing TFT, land-leasing transactions are legally protected. Any form of defective behaviors to jeopardize cooperation in land-leasing will no longer be tolerated. An agent initiated defective behavior on the land-leasing contract will expect his neighbor to defect in the future as revenge.

As many previous studies have concluded, restrictions and regulations vary widely at the village level for land leasing, which raise transaction costs and therefore reduce the total number of transaction conducted (Li, 1998; Krusekopf, 2002; Turner, et al., 2002). Village councils have direct power in exercising land policy and land trade supervision, but because councils are situated on the lowest level of the administration system, they are particularly risk-averse (cautious) regarding relaxation of existing restrictions and regulations in land policy. In short, they seek to avoid political mistakes and minimize the cost of required tasks (Li, 1998). From the farm household's point of view, reducing the fear of losing their entitled land by engaging in the land leasing market requires a clear policy and enforcement of policy.

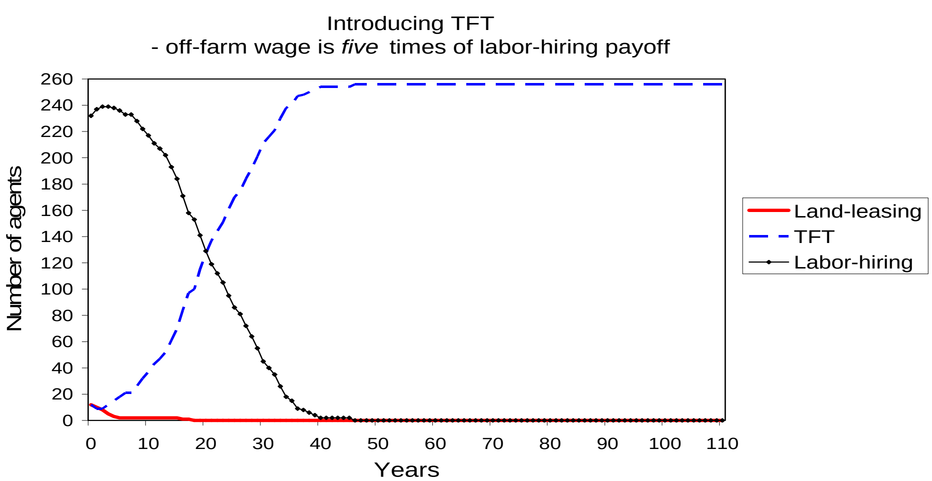


Figure 6.3.5a With 5 percent land-leasing agents, 5 percent TFT agents, and 90 percent labor-hiring agents with off-farm labor wage five times more than on-farm labor-hiring payoff

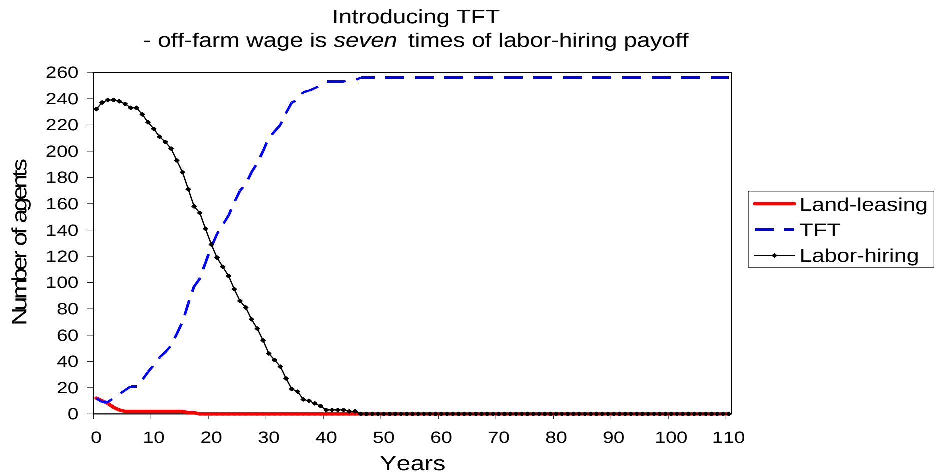


Figure 6.3.5b With 5 percent land-leasing agents, 5 percent TFT agents, and 90 percent labor-hiring agents with off-farm labor wage seven times more than on-farm labor-hiring payoff

6.4 Simulation Rationale and Discussion

In this study, game theory and ABM are combined to provide flexibility in simulating real world complexity while maintaining a solid economic theoretical foundation. Agents are allowed to make multiple decisions: labor time allocation, technology adoption, and land-leasing. What is learned from the scenarios will be useful for supplementing knowledge gained through the *ex ante* survey and key informant interviews, but also for designing the *ex post* survey for administration in the same villages in the near future. It also has been to our advantage to work on the entire procedure from designing the *ex ante* questionnaire and KI interviews, to conducting the surveys and interviews, and from coding and cleaning the survey data to conducting the econometric analyses. It is highly beneficial to understand the background of the study and people's behaviors to reinforce linkages to the simulation scenarios. It is also a valuable experience to spend weeks talking to farmers in their homes and receiving their responses towards their choices for farm and non-farm work, perceptions of new agricultural technology, and concerns for the land and village changes.

The simulations done here provide additional understanding and are suggestive of potential impacts. However, this also leads to the problem of the sensitivity issue for the parameters in the initial stage. Although sensitivity property is desirable for a simulation program, changes of parameters need to comply with realistic behaviors. There is no standard procedure to verify the results for ABM, which makes this issue more "sensitive" to discuss. Berger (2001) suggests that changing one parameter at a time may help to keep the scenario sequence tractable. The scenario sequence built into this simulation starts from the simplest assumption of perfect labor market conditions. Under the perfect labor market condition assumption and with, payoffs defined for land-leasing as triple the amount of labor-hiring, at least 17 percent of agents initially committed to land-leasing are necessary for the land-leasing strategy to expand and for the land market to develop. The higher the initial ratios, the less time is needed for the land-leasing strategy to become dominant. With 35 percent initial agents engaged in land-leasing strategy, it takes about 5 years for the land-leasing strategy to dominate over the labor-hiring strategy. The simulation results suggest that in areas where labor markets can be assumed to be perfect, with other factors kept constant, a relaxation of land rental restrictions will encourage farm households participating in the land-leasing market and the market will develop more rapidly.

Next, payoffs between off-farm and on-farm labor payoffs are altered, as one of the consequences resulting from imperfect labor market conditions, as argued by Strauss, 1986; Lopez, 1986; Benjamin, 1992. Illustrated in our simulation results, imperfect labor market conditions cast negative effects on land-leasing market development in the villages. The greater the differences between farm and nonfarm payoffs, the lower the incentive for farmers to invest in farm production. Land-leasing market formation is delayed as a result. The results confirm the study results by Benjamin and Brandt (2002) on imperfect and uneven land and labor markets in rural China that conclude that labor market development promotes farm land allocation efficiency. From a policy point of view, besides considerable efforts to remove farm land rental barriers at the village level, another policy focus should be to further develop labor markets in surrounding areas, thus reducing the transaction costs of labor off-farm work participation. The income increase from off-farm sources will also allow farm households to engage in small investment and to take on certain amounts of production risks, such as participate in land-leasing markets. As Lohmar (2001) concluded in a study of the transition of labor land and credit markets in China, the rapid growth of nonfarm employment can be expected to reduce the overall labor supply for farm production. For those still working on farm, the comparison between returns for on-farm and off-farm production encourages farmers to raise their productivity on farm.

New soybean cultivar adoption is expected to generate extra farm profit and affect farm household labor-hiring and land-leasing behaviors. The positive impact of a higher land value on land-leasing market development is straightforward. The simulation results indicate that even without proper land policies in place, by relaxing land-leasing market restrictions with new agricultural technology readily available to increase land value, farm households can be expected to switch to a land-leasing strategy. The amount of time needed for land-leasing market formation is predictable. Under the current simulation structure, it takes 14 years for the land-leasing strategy to become dominant over the labor-hiring strategy, when the payoffs to land-leasing are six times that of labor-hiring. However, the new technology impact alone on land-leasing market development is limited. Our simulation results suggest that efforts to continuously increase the relative returns to land can only shorten the land-leasing market development to a limited extent. Other policies are still needed to further speed up the adjustment. Such results may explain why in some past studies, the adoption of new crop cultivars demonstrate positive coefficients for land leasing behavior but with no statistical significance being found (Lin, 1994).

Finally, simulations of central government land policy changes as being translated through to the local level in the rural villages are developed, building upon previous scenarios. The robustness of households making land-leasing decisions emerges rapidly even without significantly increasing the land value results from new technology adoption or with failures existing in the labor market. This is modeled through use of a TFT triggering strategy.

One last important lingering question is that of 'what if' the demand for bio-fuels stimulates a soaring price for domestic soybeans in China? Is there any impact on the rate of return of out-migrants? *In other words, will farm production ever be profitable enough to slow down current migration trends or even speed up return migration?* There is no concrete answer to this critical question provided by the above simulation results, except to conclude that it would take extreme alterations to the land-labor payoff matrix to simulate this reverse trend. In general, with 0.08 ha/capita in land resource, farm production will not be able to stop or reverse the migration trend. However, with increasing off-farm employment opportunities, the development of transferable land use rights may help some households achieve economies of scale by consolidating farm land.

Using the ABM with game theory approach provides greater flexibility to create simulation scenarios and the spectrum of predictions has solid theoretical background. However, the simulation approach also generates certain limitations. As Moss (2001) righteously points out, when artificial data are created to illustrate a particular reality phenomenon, they are not empirically confirmed. However, in game theory, there is a similar tendency avoid direct contact with data and empirical systems. Mathematical solutions substitute references to concrete data in most game theory studies. Hanneman and Patrick (1997) suggest it is acceptable to take predictions that arise from naturalistic observed data, until a more accurate or simpler tool can be found. We hope in the near future, when land market data become available and/or when the *ex post* survey is undertaken, efforts to further develop ABM simulation models will force a strong linkage with the empirical data. The interpretation of simulation results will then help guide policy reform more precisely. In the current stage, using the agent-based modeling structure to simulate the reality phenomenon provides a good complimentary approach to existing economics theory and econometric results. It is essential to fully understand the results obtained by the traditional approach with reasonable goals for what ABM can achieve.

Chapter 7

SUMMARY AND CONCLUSIONS

7.1 Introduction

This dissertation investigates three major issues concerning resource allocation, decision-making, and land-leasing and labor-hiring behaviors in rural south China, as part of a project for the McKnight Foundation on low-phosphorous soybean technologies. Under the profound impact of labor rural-urban migration trends, household members engage in on-farm, off-farm, off-farm self-employment and home production to maximize welfare. Since labor time is viewed as a resource, which is assignable and tractable, the allocation of labor time can be used to recover the intrahousehold nonlabor income sharing rule. The sharing rule results reveal how pooled income is distributed within a household, which sheds light on intrahousehold inequality and welfare analysis.

The inclusion of the sharing rule and individual labor income aids in recovering of the generalized household decision-making structure, which is focused in this dissertation on four sets of decisions important to farm households: consumption, production, marketing and innovation. A set of potentially influential variables, including distances to off-farm jobs that take household members away from the farm origin as well as remittance amounts are included in the estimations to begin to understand the influence of spatial mobility on decision-making at the origin. Of particular interest is to what extent the 'next generation' – many of whom are working outside the south China's rural areas – is involved in making farm decisions and those related to innovation.

It is hypothesized that the analysis of new technology adoption cannot be isolated from labor out-migration impacts on farm production behaviors. For example, when new soybean cultivars are released and readily available, the expectation of adoption and diffusion not only relies on marketing conditions but also is believed to be closely tied to intrahousehold decision-making structure and labor availability under rural-to-urban labor migration impact. Farmers participating in the household survey on which this dissertation is based expressed (keen) interest in the new cultivars but also conceded that the next generation could be unlikely to farm, except as a means to retain land allocated to the household.

The research uses *ex ante* agricultural household surveys coupled with key informant interviews conducted in south China in summer, 2006. The household survey was carried out as the baseline socioeconomic survey for a project funded by McKnight Foundation to assess the impacts of development of P-efficient soybeans; the survey was designed to provide an initial understanding of crop production (including soybean production decisions and anticipated adoption decisions), labor time allocation, land holding behaviors, and soybean and soybean product markets in the south China region. The survey was conducted in three provinces in south China (Guangdong, Guangxi, and Hunan), and included household sampled from villages in 5 counties (Yingde, Xintian, Longan, Laibin, and Guilin). A total 247 surveys were collected. Data provide insights into household decision-making (and decision rules) regarding land, labor and technology choices.

The household collective model serves as the major modeling framework, which decentralizes the household decision-making process with respect to individuals' preferences and reaches a collective outcome of individual members' rational behaviors. Interactions among household members contribute to inequality issues in resource sharing. Due to imperfect land and labor markets in rural south China and rigid administrative system control for labor migration and land transfer, these aspects are included in the analyses. Furthermore, investigation of interactions of inter-household labor-hiring and land-leasing behaviors becomes intriguing and generates a spectrum of scenarios when altering farm technology, the labor market and land market conditions. Agent-based model simulations are employed to analyze how changes in technology (i.e., adoption and diffusion of P-efficient soybeans) under conditions of strong labor out-migration could influence farm household land and labor resource allocation in the region.

Finally, the strong out-migration trend raises the overriding question of how soybean production and ultimately farm structure and land policy might change in the long term to allow greater production to take place. The high urban-rural wage ratio can be expected to reduce incentives to transform agriculture in this region -- now dominated by many small farms -- to adopt more productive technologies, such as P-efficient soybeans. However, if changes in land-leasing markets occur that allow farms to expand in size, the outcome could be very different. This could be particularly the case given the low labor (and fertilizer) input requirements of the new P-efficient soybean cultivars.

7.2 Results

Econometric model results. The analysis of total labor supply shows that husband's labor supply responds positively to an increase in own MPL, but responds negatively to an increase in the wife's MPL. In contrast, the wife's labor supply behavior is not found to be affected by own MPL or husband's MPL. This may due to the traditional social norm in rural south China that wives and females more generally care for family; the reduced hours spent on farm and nonfarm work are compensated by higher hours of home production. As nonlabor (pooled) income increases, husbands are found to allocate less time to work, but farm land size positively affects husband's total working time. Schooling is a proxy variable used for human capital in the regressions. It is found to have a negative effect on wife's total labor supply, indicating that wives with more education work fewer hours.

The sharing rule results reveal that MPL has an impact on the transferring of nonlabor (pooled) income between spouses. In general, wives behave in a more altruistic manner than husbands. An increase in wife's MPL is found to lead to a positive transfer of nonlabor income to her husband. However, for the same unit increase in husband's MPL, he can be expected to gain more in nonlabor (pooled) income. An increase in the number of male migrants leads to a positive transfer of nonlabor income share to his wife, as expected

The general household decision-making structure is a *reflection* of how household power is distributed among household members. Different decision-making perspectives are likely to relate to family resource factors (i.e., labor income effect, nonlabor income effect), work participation decisions (i.e., farm work, nonfarm work, nonfarm self-employment, and household work), spatial distance (i.e., work distance from home), or other household and individual characteristics (i.e., age, schooling, sex ratio, etc.). Yet, while many of the above factors may influence engagement in *(inclusion in)* household decision-making, it is very difficult albeit impossible -- without extremely careful observation of the actual decision-making process -- to determine *who* has the 'final word' on decisions, regardless of type (consumption, production, marketing and innovation). But each factor can be explored in terms of influence on intrahousehold decision-making structure to indicate involvement in the decision-making process. Some major findings are summarized as follows:

A higher sharing rule ratio suggests more nonlabor income is allocated to the wife. Significant effects are found on her making decisions independently on marketing decisions, trying new ideas at home, and some production decisions (fertilizer usage and farm equipment purchases). However, we did not find a statistically significant effect of the sharing rule on making decisions relative to innovation, including adoption of new crop cultivars or decisions related to trying out new ideas on the farm. The sharing rule ratio also was shown to have no impact on making decisions on household consumption. An increase in the sharing rule ratio also predicts a more balanced household decision-making structure in general. It is more likely for husband and wife or other household members involved in making multiple joint decisions, relative to the husband making decisions alone. The results for the sharing rule, therefore, suggest that while a greater share of pooled income allocated to the wife is likely to increase her engagement in making a number of decisions alone, such increases also suggest greater household engagement in the process overall.

The labor income effects are measured through the MPL for both husband and wife. Since off-farm labor wage well exceeds farm shadow wage, when the MPL value increases, the measure of labor time value shifts from farm work productivity to off-farm work productivity. Wife's MPL negatively impacts her making decisions alone on some production decisions (crops types, soybean production, and farm equipment purchases) and some innovation decisions (trying new ideas on the farm, trying new ideas at home). But a higher wife MPL increases her involvement in making decisions jointly with her husband. An interesting finding is that it is more likely for adult males making joint decisions as a result of an increased MPL for either husband or wife. These findings suggest that when the husband and wife are more engaged in off-farm work, the adult sons are involved in the farm household decision-making structure increases.

Off-farm work participation behaviors show significant impacts on farm production decisions. Male's off-farm work participation behavior predicts an increase in female's decision-making engagement. The wife's off-farm work participation behavior significantly reduces her involvement in making decisions alone on what types of livestock to keep or what to feed livestock. Furthermore, the husband's home production participation increases the chance that the husband and wife make joint decisions on seven out of fifteen decisions. This result suggests that husband's participation in home production provides a good indication of husband and wife's joint decision-making structure, relative to a husband-dominant household decision-making structure. Also, household members' time spent on home production alters their decision engagement (and likely power) relative to farm production activities. This is not surprising: farm production and home production are often closely integrated activities in agricultural households in developing countries.

The results based on the work distance measures show that the involvement of household males making joint decisions on soybean cultivar adoption is negatively affected by the work distance of the husband, but positively affected by the work distance of the wife. The likelihood of the wife making decisions alone generally was not affected by an increase in the husband's work distance in the estimated models. The oldest adult child's work distance is used to predict possible effects of out-migration of the 'next generation' on household decision-making structure. The regression results show no significant effects. However, estimation results for remittances suggest that the higher the amount of remittances that adult children remit to the household, the more likely they are to be engaged in household decision-making. Significant positive effects are found on household males making particular joint decisions relative to the husband making decisions alone. Specific decisions influenced by level of remittances include soybean production, farm equipment purchases, marketing crops, engaging in contract farming, new crop cultivar adoption, and trying new ideas out at home. Such results suggest that off-farm migration – particularly though remittance income transfer -- importantly influences household decision-making structure. The financial support of households at the origin by those engaging in off-farm migration appears to provide them with a voice in making a broad array of decisions. That is, it is unlikely that out-migration results in only those at the origin making decisions that are likely to have broad implications in a multi-generational sense and for China's future.

Agent-based model (ABM) results. To illustrate the interactions among off-farm work participation, on-farm labor-hiring behavior and farm-land leasing behavior, Recursive Porous Agent Simulation Toolkit (Repast) is employed to simulate the interactions of agents and their emergent collective behaviors, assuming that each agent makes rational decisions based on potential payoffs associated with the chosen strategy. We use relative ratios in the payoff matrix; the gradually increased parameter values bounded within certain ranges in the payoff ratios and the initial population size with percentages pursuing each strategy help prevent unexplainable scenarios.

Under perfect labor market conditions and payoffs defined for land-leasing as triple the amount of labor-hiring, at least 17% of agents initially committed to land-leasing are necessary the for land-leasing strategy to expand and for the land market to develop. The higher the initial ratios, the less time needed for the land-leasing strategy to become dominant. With 35% of the initial agents engaged in a land-leasing strategy, it takes about 5 years for this strategy to dominate over the labor-hiring strategy. The ABM simulation results suggest that in areas where labor markets can be assumed to be perfect (other factors held constant), simply relaxing land rental restrictions will encourage farm households to participate in the land leasing market and market development speed can be predicted.

Next, the payoffs between off-farm and on-farm labor payoffs are altered, which can be considered as a result of imperfect labor market conditions. Illustrated in our simulation results, the imperfect labor market condition casts a negative effect on land-leasing market development in villages. The greater differences between farm and nonfarm payoffs, the lower the incentive for farmers to invest in farm production. Households with extra labor can be expected to actively search for off-farm work opportunities, since the payoff is the same as leasing-in land. The land-leasing market formation process is delayed as a result. The results confirm the Benjamin and Brandt (2002) study on imperfect and uneven land and labor markets in rural China that showed that labor market development promotes farm land allocation efficiency, although the growth in off-farm opportunities alone cannot eliminate such inefficiency. From a policy point of view, besides the considerable efforts for removing farm land rental barriers that are needed at the village level, another policy focus would be to further develop labor markets in surrounding areas and reduce the transaction costs associated with off-farm employment. The income from off-farm sources can be expected to allow farm households to engage in small investments and may result in greater willingness to take on certain amounts of production risk, such as participating in the land-leasing market.

When new agricultural technology is readily available, in this specific case new soybean cultivars, adoption is expected to generate extra farm profit and affect farm household labor-hiring and land-leasing behaviors. A positive impact of a higher land value on land-leasing market development is assumed. The simulation results indicate that even without land policies that relax land-leasing market restrictions, with new agricultural technology readily available to increase land value, households can be expected to shift to a land-leasing strategy. The amount of time needed for land-leasing market formation is shortened. However, new technology impact alone on land-leasing market development is limited. Our simulation results suggest that efforts to continuously increase the relative returns to land can only shorten the time needed for land-leasing market development. Other policies will still be required to further speed up the process of land-leasing market formation. Such results may explain why in some past studies, the adoption of new crops cultivars show positive coefficients in models of land leasing behavior but no statistical significance is found (Lin, 1994).

Finally, land policy impacts on land-leasing market development in the villages are explored, building upon previous scenarios but with a TFT triggering strategy included. The robustness of households making land-leasing decisions emerges rapidly even under imperfect labor market conditions. From the farm household's point of view, reducing the fear of losing their entitled land and engaging in the land-leasing market requires that land policies be enforced at the village level. The enforcement of policy being encouraged by the central administration should protect land-leasing transactions and increase farm household confidence in cooperation in land-leasing markets.

7.3 Limitations of This Study

Our survey procedure generated a unique dataset, which is tailored to this dissertation. However, despite its usefulness and value as a baseline dataset, the *ex ante* data provide no information on *changes* in farm and non-farm production, labor supply behaviors, various perspectives of household decision-making, as well as dynamic land-leasing and labor-hiring behaviors over time. The dataset is also relatively small, given the difficulty inherent in collecting richly-detailed data from a larger number of households across multiple sites in rural south China. No doubt, a larger dataset with multiple survey periods would allow for a more comprehensive econometric analysis. Completion of the follow-up *ex post* survey should provide for a richer estimation experience, where the impacts of introduction of the new soybean cultivars can be understood. Further, measuring the impact of soybean price changes over time would be of great research interest to us, as prices can affect farm labor supply, alter land allocation decisions, and influence adoption and diffusion of the new P-efficient soybean cultivars in the south China region.

Another drawback to the estimation is the sample selectivity issue. While our survey results properly reflect the aging structure of rural China, where farm production is taken care of by an older population, the relationships reported in this research are specific to this older population. If it had been possible to survey all household members, and especially young couples, different relationships might have emerged. The younger population in rural south China are likely to differ in substantial ways from their parents and grandparents, simply given their greater familiarity and experience with urban/peri-urban culture. The intrahousehold sharing rule that is negotiated, total labor supply and decision-making structure could be quite different among younger couples, as a result.

The validation and calibration on the simulation results are also important issues in this dissertation. Simulation results are analyzed based on a game-theoretic structure and can only be further validated when survey or census data become available. When answering the what-if questions during simulation, important questions may involve what if the demand for bio-fuel stimulates a soaring price for domestic soybeans? Also, will farm production ever be profitable enough to slow down current migration trends or speed up return migration? And is there any impact of the rate of returning migrants on farm production and land-leasing behaviors? There are no definitive answers provided to these questions from the simulation results reported in Chapter 6 but further analysis could provide insight. Overall, it is likely that it would take extreme changes in the land-labor payoff matrix to simulate a reverse trend from the strong out-migration trend now observed. However, with increasing off-farm employment opportunities, transferable land use rights may help some households to achieve the economies of scale by consolidating farm land. Thus, while out-migration may not be abated, changes in land markets could result in the higher levels of food production necessary for China.

7.4 Future Research

This dissertation provides a good understanding of individual household member's labor supply behavior (for the primary couple), intrahousehold nonlabor income allocation and factors influencing reliance on different household decision-making structures. The research also provides insight into interactions among households (agents) within villages, when the economic payoffs provide different incentives and also when social norms are introduced in a simplified way. The next step is to undertake the *ex post* survey to help understand the changes that have taken place within households and at the village level since summer, 2006. Since multiple varieties of the P-efficient soybean cultivars have now been released by the government, actual adoption and diffusion can be measured and barriers to adoption documented and better understood. *Anticipated* adoption behaviors reported in the *ex ante* survey can then be compared to *actual behaviors post release*.

In addition, to extend the current work, it could be quite interesting to integrate social and economic network analyses and effects with our econometric models and the agent-based modeling framework. While this integration would be useful for the ex *ante* data analysis, it would be even more powerful for analyzing the combined *ex ante* and *ex post* data. Although network effects are well recognized in the technology innovation adoption and diffusion literature, few studies have related network typology, and particularly multi-dimensional network typology, with individual household member's engagement in technology decision making and changes in intrahousehold resource allocation and welfare. An intra-village network approach coupled with intra-household analyses could lead to new research that produces convincing results to help explain the increasingly complex social-economic system and its impacts on households and the individual members that comprise them.

BIBLIOGRAPHY

Apps, P. F. and R. Rees (1996). "Labour Supply, Household Production and Intra-Family Welfare Distribution." Journal of Public Economics 60(2): 199-219.

Apps, P. F. and R. Rees (1997). "Collective Labor Supply and Household Production." The Journal of Political Economy 105(1): 178-90.

Apps, P. and R. Rees (1999). "On the Taxation of Trade within and between Households." Journal of Public Economics 73(2): 241-63.

Aryal, J. P. (2005). "Assessing the Impact of Remittance Income on Household Welfare and Land Conservation Investment in Mardi Watershed of Nepal: A Village General Equilibrium Model." Working Paper. http://www.feem-web.it/ess/ess05/files/Aryal.pdf

Ash, R. F. and R. L. Edmonds (1998). "China's Land Resources, Environment and Agricultural Production." The China Quarterly 156: 836-79.

Au, C.-C. and J. V. Henderson (2006). "How Migration Restrictions Limit Agglomeration and Productivity in China." Journal of Development Economics 80(2): 350-88.

Axelrod, R. (1984). The Evolution of Cooperation. New York: Basic Books.

Barreteau, O., F. Bousquet and J. Attonaty (2001). "Role-Playing Games for Opening the Black Box of Multi-Agent Systems: Method and Lessons of Its Application to Senegal River Valley Irrigated Systems." Journal of Artificial Societies and Social Simulation 4(2) http://www.soc.surrey.ac.uk/JASSS/4/2/5.html

Bartlett, H. and D. R. Phillips (1997). "Ageing and Aged Care in the People's Republic of China: National and Local Issues and Perspectives." Health & Place 3(3): 149-59.

Bartlett, M. and D. Kazakov (2004). "The Role of Environmental Structure in Multiagent Simulations of Language evolution." In Proceedings of the Fourth Symposium on Adaptive Agents and Multi-Agent Systems (AAMAS-4), AISB convention. Leeds, UK.

Basu K. (2006). "Gender and Say: A Model of Household Behaviour With Endogenously Determined Balance of Power." Economic Journal 116(511): 558-580.

Batty, M., B. Jiang, and M. Thurstain-Goodwin (1999). "Local Movement: Agent-Based Models of Pedestrian Flows." Working Paper 4, Centre for Advanced Spatial Analysis, University College, London.

Becker, G. S. (1965). "A Theory of the Allocation of Time." The Economic Journal 75(299): 493-517.

Benin, S., M. Ahmed, J. Pender and S. Ehui (2005). "Development of Land Rental Markets and Agricultural Productivity Growth: The Case of Northern Ethiopia." Journal of African Economies 14(1): 21-54.

Benjamin, D. (1992). "Household Composition, Labor Markets, and Labor Demand: Testing for Separation in Agricultural Household Models." Econometrica 60(2): 287-322.

Benjamin, D. and L. Brandt (2002). "Property Rights, Labour Markets, and Efficiency in a Transition Economy: The Case of Rural China." Canadian Journal of Economics 35(4): 689-716.

Berger, T. (2001). "Agent-Based Spatial Models Applied to Agriculture: a Simulation Tool for Technology Diffusion, Resource Use Changes and Policy Analysis." Agricultural Economics 25(2): 245-60.

Berger, T., R. Birner, J. D´ıaz, N. McCarthy and H. Wittmer (2007). "Capturing the Complexity of Water Uses and Water Users within a Multi-Agent Framework." Water Resources Management 21(1): 129-48.

Birkhaeuser, D., R. E. Evenson and G. Feder (1991). "The Economic Impact of Agricultural Extension: A Review." Economic Development and Cultural Change 39(3): 607-50.

Borgers, A. and H. Timmermans (1993). "Transport Facilities and Residential Choice Behavior: A Model of Multi-Person Choice Processes." Papers in Regional Science 72(1): 45-61.

Bourguignon, F. and P.-A. Chiappori (1992). "Collective Models of Household Behavior: An Introduction." European Economic Review 36(2-3): 355-64.

Bowlus, A. J. and T. Sicular (2003). "Moving Toward Markets? Labor Allocation in Rural China." Journal of Development Economics 71(2): 561-83.

Boyd, M. M. (1989). "Family and Personal Networks in International Migration: Recent Developments and New Agendas." The International Migration Review 23(3): 638-70.

Breman, H., J. J. R. Groot and H. van Keulen (2001). "Resource Limitations in Sahelian Agriculture." Global Environmental Change 11(1): 59-68.

Brown, L. R. (1995). Who Will Feed China? Wake-up Call for a Small Planet. New York: Worldwatch Institute.

Brown, D., R. Riolo, D. T. Robinson, M. North, and W. Rand (2005). "Spatial Process and Data Models: Toward Integration of Agent-based Models and GIS." Journal of Geographical Systems 7(1):25-47.

Browning, M., F. Bourguignon, P.-A. Chiappori, and V. Lechene (1994). "Income and outcomes: A structural model of intrahousehold allocation." Journal of Political Economy 102(6): 1067-96.

Browning, M. and P.-A. Chiappori (1998). "Efficient Intra-Household Allocations: A General Characterization and Empirical Tests." Econometrica 66(6): 1241-78.

Browning, M. (2000). "The Saving Behaviour of a Two Person Household." Scandinavian Journal of Economics 102(2): 235-51.

Browning, M., P.-A. Chiappori, and Lewbel, A. (2003). "Estimating Consumption Economies of Scale, Adult Equivalence Scales, and Household Bargaining Power." CAM, University of Copenhagen, Working Paper.

Burke, R. V. (1979). "Green Revolution Technologies and Farm Class in Mexico." Economic Development and Cultural Change 28(1):135-54.

Caiumi, A. and F. Perali (2000). "Children and Intrahousehold Distribution of Resources: An Estimate of the Sharing Rule of Italian Households." Working Paper No. 7/2000, CHILD.

Castella, J., T. N. Trung, and S. Boissau (2005). "Participatory Simulation of Land-Use Changes in the Northern Mountains of Vietnam: the Combined Use of an Agent-Based Model, a Role-Playing Game, and A Geographic Information System." Ecology and Society 10(1):27-59.

Carter, C. A. (1997). "The Urban-Rural Income Gap in China: Implications for Global Food Markets." American Journal of Agricultural Economics 79(5): 1410-18.

Chan, K. W. (1994). "Urbanization and Rural-Urban Migration in China since 1982 - A New Baseline." Modern China 20(3): 243-81.

Chen, S. and C. Yeh (2001). "Evolving Traders and the Business School with Genetic Programming: A New Architecture of the Agent-Based Artificial Stock Market." Journal of Economic Dynamics and Control 25(3): 363-93.

Chen, T. and M. Selden (1994). "The Origins and Social Consequences of China's Hukou System." The China Quarterly 139: 644-68.

Chen, Y. and C. Hoy (2008). "Rural Migrants, Urban Migrants and Local Workers in Shanghai: Segmented or Competitive Labour Markets?" Built Environment 34(4): 499-516.

Chiappori, P. -A. (1988a). "Rational Household Labor Supply." Econometrica 56(1): 63-90.

Chiappori, P. -A. (1988b). "Nash-Bargained Households Decisions: A Comment." International Economic Review 29(4): 791-96.

Chiappori, P.-A. (1992). "Collective Labor Supply and Welfare." The Journal of Political Economy 100(3): 437-67.

Chiappori, P. -A. (1997). "Introducing Household Production in Collective Models of Labor Supply." The Journal of Political Economy 105(1): 191-204.

Chiappori, P.-A., B. Fortin and G. Lacroix (2002). "Marriage Market, Divorce Legislation, and Household Labor Supply." The Journal of Political Economy 110(1): 37-72.

Chiuri, M. C. (2000). "Individual Decisions and Household Demand for Consumption and Leisure." Research in Economics 54(3):277-324.

Ciaian, P. and J. F. M. Swinnen (2006). "Land Market Imperfections and Agricultural Policy Impacts in the New EU Member States: A Partial Equilibrium Analysis." American Journal of Agricultural Economics 88(4): 799-815.

Cioffi-Revilla, C. and N. M. Gotts (2003). "Comparative Analysis of Agent-based Social Simulations: Geosim and FEARLUS Models " Journal of Artificial Societies and Social Simulation 6(4) http://jasss.soc.surrey.ac.uk/6/4/10.html

Croll, E. J and H. Ping (1997). "Migration for and against Agriculture in Eight Chinese Villages." The China Quarterly 149(1): 128-46.

Corfman, K. P. and D. R. Lehmann (1987). "Models of Cooperative Group Decision-Making and Relative Influence: An Experimental Investigation of Family Purchase Decisions." The Journal of Consumer Research 14(1): 1-13.

Couprie, H. (2007). "Time Allocation within the Family: Welfare Implications of Life in a Couple." The Economic Journal 117(516): 287-305.

Curran, D. and C. O'Riordan (2007). "Cultural Learning in a Dynamic Environment: an Analysis of Both Fitness and Diversity in Populations of Neural Network Agents." Journal of Artificial Societies and Social Simulation 10(43). http://jasss.soc.surrey.ac.uk/10/4/3.html

Darmon E. and D. Torre (2004) "Adoption and Use of Electronic Markets: Individual and Collective Learning." Journal of Artificial Societies and Social Simulation 7(2): 1-12. http://jasss.soc.surrey.ac.uk/7/2/2.html

Davin, D. (1996). "Gender and Rural-Urban Migration in China." Gender and Development 4(1): 24 -30.

Davidson and Mackinnon (1993). Estimation and Inference in Econometrics. Oxford: Oxford University Press.

de Brauw, A., Q. Li, C. Liu, S. Rozelle and L. Zhang (2008). "Feminization of Agriculture in China? Myths Surrounding Women's Participation in Farming." The China Quarterly 194: 327-48.

de Janvry, A. and E. Sadoulet (2001). "Income Strategies among Rural Households in Mexico: The Role of Off-farm Activities." World Development 29(3): 467-80.

Deadman, P. and R. H. Gimblett (1994). "The Role of Goal-oriented Autonomous Agents in Modeling People-environment Interactions in Forest Recreation." Mathematical and Computer Modeling 20(8): 121-33.

Deininger, K. W. (2003a). Land Policies for Growth and Poverty Reduction. Washington: World Bank and Oxford University Press.

Deininger, K. W. (2003b). “Land Markets in Developing and Transition Economies: Impact of Liberalization and Implications for Future Reform” American Journal of Agricultural Economics 85(5): 1217-22.

Deininger, K. and S. Jin (2005). "The Potential of Land Rental Markets in the Process of Economic Development: Evidence from China." Journal of Development Economics 78(1): 241-70.

Démurger, S and H. Xu (2010). "Return Migrants: The Rise of New Entrepreneurs in Rural China." GATE Working Paper No. 1008.

Dercon, S. (2002). "Income Risk, Coping Strategies, and Safety Nets." The World Bank Research Observer 17(2): 141-67.

Dijkstra, J., H. J. P. Timmermans and A. J. Jessurun (2000). "A Multi–Agent Cellular Automata System for Visualising Simulated Pedestrian Activity." In: S. Bandini and T. Worsch (Eds.) Theoretical and Practical Issues on Cellular Automata. Proceedings on the 4th International Conference on Cellular Automata for research and Industry, Springer Verlag.

Dissart, J. C. and S. C. Deller (2000). "CPL Bibliography 360: Quality of Life in the Planning Literature." Journal of Planning Literature 15: 135-61.

Donni, O. (2008). "Labor Supply, Home Production, and Welfare Comparisons." Journal of Public Economics 92(7): 1720-37.

Doss, C. R. (1996). "Testing among Models of Intrahousehold Resource Allocation." World Development 24(10): 1597-609.

Doss, C. R. (2006). "Analyzing Technology Adoption using Microstudies: Limitations, Challenges, and Opportunities for Improvement." Agricultural Economics 34(3): 207-19.

Du, Y., A. Park and S. Wang (2005). "Migration and rural poverty in China." Journal of Comparative Economics 33(4): 688-709.

Earl, M. G. and R. D'Andrea (2002) "Modeling and Control of A Multi-Agent System Using Mixed Integer Linear Programming." Proceedings of the 41st IEEE Conference on Decision and Control, Las Vegas, Nevada USA.

Epstein, J. M., and R. L. Axtell (1996). Growing Artificial Societies: Social Science from the Bottom Up. Cambridge, Massachusetts, and Washington DC: MIT Press and the Brookings Institute.

Estudillo, J. P. and K. Otsuka (1999). "Green Revolution, Human Capital, and Off-Farm Employment: Changing Sources of Income among Farm Households in Central Luzon, 1966-94." Economic Development and Cultural Change 47(3): 497-523.

Eubank, S., H. Guclu, V. S. A. Kumar, M. V. Marathe, A. Srinivasan, Z. Toroczkai and N. Wang (2004). " Modelling Disease Outbreaks in Realistic Urban Social Networks." Nature 429 (6988): 180-4.

Evans, T. P. and H. Kelley (2004). "Multi-Scale Analysis of a Household Level Agent-Based Model of Landcover Change." Journal of Environmental Management 72 (1): 57-72.

Evenson, R. M. (2001). "Economic Impacts of Agricultural Research and Extension." In: B. Gardner and G. Rausser (Eds.) Handbook of Agricultural Economics, New York: Elsevier Science.

Evenson, R. E. and D. Gollin (2003). "Assessing the Impact of the Green Revolution, 1960 to 2000." Science 300(2): 758-63.

Fan, C. C. (1999). "Migration in a Socialist Transitional Economy: Heterogeneity, Socioeconomic and Spatial Characteristics of Migrants in China and Guangdong Province." International Migration Review 33(4): 954-87.

Fan, C. C. (2005). "Interprovincial Migration, Population Redistribution, and Regional Development in China: 1990 and 2000 Census Comparisons." The Professional Geographer 57(2): 295-311.

Feder, G. (1982). "Adoption of Interrelated Agricultural Innovations: Complementarity and the Impacts of Risk, Scale, and Credit." American Journal of Agricultural Economics 64(1): 94-101.

Feder, G. and D. L. Umali (1993). "The Adoption of Agricultural Innovations: A Review." Technological Forecasting and Social Change 43(3-4): 215-39.

Feder, G., R. E. Just, and D. Zilberman (1985). "Adoption of Agricultural Innovations in Developing Countries: A Survey." Economic Development and Cultural Change 33(2):255-98.

Feng, S. and N. Heerink (2008). "Are Farm Households' Land Renting and Migration Decisions Inter-related in Rural China?" NJAS - Wageningen Journal of Life Sciences 55(4): 345-62.

Findeis, J., H. Swaminathan, and A. Jayaraman (2005). "Agricultural Households in the U.S.: Participation in Labor, Decision-making, and the Effects of Farm Asset Control." Economie Rurale (289-290): 44-62.

Fischer, G. and L. Sun (2001). "Model Based Analysis of Future Land-Use Development in China." Agriculture, Ecosystems & Environment 85(1): 163-76.

Fleisher, B. M. and D. T. Yang (2006). "Problems of China's Rural Labor Markets and Rural-Urban Migration." Chinese Economy 39(3): 6-25.

Food and Agriculture Organization of the United Nations (FAO) data: http://faostat.fao.org/site/342/default.aspx

Fuglie, K. O. and C. A. Kascak (2001). "Adoption and Diffusion of Natural-Resource-Conserving Agricultural Technology." Applied Economic Perspectives and Policy 23(2): 386-403.

Gao X. (1994). "China's Modernization and Changes in the Social Status of Rural Women." In: C K Gilmartin, G Hershatter, L Rofel, T White (Eds.) Engendering China: Women, Culture, and the State. Cambridge, MA: Harvard University Press, Gjerdrum, J., N. Shah, L. G. Papageorgiou (2001). "A Combined Optimization and Agent-based Approach to Supply Chain Modelling and Performance Assessment." Production Planning and Control 12(1): 81-8.

Gould, D. M. (1994). "Immigrant Links to the Home Country: Empirical Implications for US Bilateral Trade Flows." The Review of Economics and Statistics 76(2): 302-16.

Gravemeyer, S., T. Gries and J. Xue (2010). "Income Determination and Income Discrimination in Shenzhen." Urban Studies 47(10): 1-19.

Greene, W. H. (2002). Econometric Analysis. Prentice Hall, 5th edition.

Gupta, M. R. (1987). "Rural-Urban Migration and Urban Unemployment: A Note." Scottish Journal of Political Economy 34(3): 295-305.

Ha, W., J. Yi and J. Zhang (2009). "Internal Migration and Income Inequality in China: Evidence from Village Panel Data." United Nations Development Programme Human Development Reports Research Paper.

Haddad, L. J., J. Hoddinott and H. Alderman (1997). Intrahousehold Resource Allocation in Developing Countries: Models, Methods, and Policy. Johns Hopkins University Press, MA.

Hanneman, R. and S. Patrick (1997). "On the Uses of Computer-Assisted Simulation Modeling in the Social Sciences." Sociological Research Online 2(2) *http://www.socresonline.org.uk/2/2/5.html*

Harris, J. R. and M.P. Todaro (1970). "Migration, Unemployment and Development: A Two-Sector Analysis." The American Economic Review 60(1): 126-42.

Harris, J. M. and S. Kennedy (1999). "Carrying Capacity in Agriculture: Global and Regional Issues." Ecological Economics 29(3): 443-61.

Hayami, Y. and K. Otsuka (2004). "Role of Agricultural Research in Poverty Reduction: Lessons from the Asian Experience." Food Policy 25(4): 447-62.

Helbing, D. (1992). "A Fluid Dynamic Model for the Movement of Pedestrians." Complex Systems 6: 391-415. http://www.theo2.physik.unistuttgart.de/helbing.htm

Helbing, D. and P. Molnar (1997). "Self-Organization Phenomena in Pedestrian Crowds." In: F. Schweitzer (Ed.) Self-Organization of Complex Structures: From Individual to Collective Dynamics. Gordon & Beach, London.

Hertel, T. and F. Zhai (2006). "Labor Market Distortions, Rural-Urban Inequality and the Opening of China's Economy." Economic Modelling 23(1): 76-109.

Hoddinott, J. (2003). "A Model of Migration and Remittances Applied to Western Kenya." Oxford Economic Papers 46(3): 459-76.

Hoff, K., A. Braverman and J. Stiglitz (1993). The Economics of Rural Organization: Theory, Practice, and Policy. Oxford: Oxford University Press.

Holden, S. T. and H. R. Binswanger (1998). "Small-Farmer Decisionmaking, Market Imperfections, and Natural Resource Management in Developing Countries." In: Lutz E., H. Binswanger, P. Hazell and A. McCalla (Eds.) Agriculture and the Environment: Perspectives on Sustainable Rural Development, World Bank Publications.

Holden, S., C. B. Barrett, and F. Hagos. (2006). "Food-for-Work for Poverty Reduction and the Promotion of Sustainable Land Use: Can It Work?" Environment and Development Economics 11(1): 15-38.

Hu, D. (2002). "Trade, Rural-Urban Migration, and Regional Income Disparity in Developing Countries: A Spatial General Equilibrium Model Inspired by the Case of China." Regional Science and Urban Economics 32(3): 311-38.

Huang, X. (1999). "Ground-Level Bureaucrats as a Source of Intensification of Rural Poverty in China." Journal of International Development 11(4): 637-48.

Huang J., S. Rozelle, and F. Rosegrant (1999). "China's Agriculture, Trade and Productivity in the 21st Century." Chinese Agriculture and the WTO, Proceedings of WCC-101 Meeting, Seattle, WA.

Huang, J., Hu, R., van Meijl, H., and van Tongeren, F. (2003). "Economic Impacts of Genetically Modified Crops in China." In Proceeding of 25th International Conference of Agricultural Economists Durban, South Africa.

Hubbard, R. G. (1998). "Capital-Market Imperfections and Investment." Journal of Economic Literature 36(1): 193-225.

Ilahi, N. (1999). "Return Migration and Occupational Change." Review of Development Economics 3(2): 170-86.

Iqbal, A., I. A. Khalil, N. Ateeq, and M. Sayyar Khan (2006). "Nutritional Quality of Important Food Legumes." Food Chemistry 97(2): 331-35.

Irwin, E. G. and N. E. Bockstael (2002). "Interacting Agents, Spatial Externalities and the Evolution of Residential Land Use Patterns." Journal of Economic Geography 2(1): 31-54.

Irwin, E. G., Bell, K., Geoghegan, J. (2003). "Modeling and Managing Urban Growth at the RuraL-urban Fringe: A Parcel-level Model of Residential Land Use Change." Agricultural and Resource Economics Review 32(1): 83-102.

Itami, R. M. and H. R. Gimblett (2001). "Intelligent Recreation Agents in a Virtual GIS World." Complexity International Journal (8) http://www.complexity.org.au/ci/vol08/itami01/

Izquierdo S. S., L. R. Izquierdo and N. M. Gotts (2008). "Reinforcement Learning Dynamics in Social Dilemmas." Journal of Artificial Societies and Social Simulation 11(21): 1-22. http://jasss.soc.surrey.ac.uk/11/2/1.html

Jacoby H. (1989). A Shadow Wage Approach to Estimate a Labor Supply Model for Peasant Households: An application to the Peruvian Sierra. Dissertation. University of Chicago.

Jacoby, H. (1993). "Shadow Wages and Peasant Family Labor Supply: An Econometric Application to the Peruvian Sierra." Review of Economic Studies 60(4): 903-22.

Just, R. E. and D. Zilberman (1983). "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." Oxford Economic Papers 35(2): 307-28.

Kalugina, E., N. Radtchenko and C. Sofer (2009). "How Do Spouses Share Their Full Income? Identification of the Sharing Rule Using Self-Reported Income." The Review of Income and Wealth 55(2): 360-91.

Kilic, T., C. Carletto, J. Miluka and S. Savastano (2009). "Rural Nonfarm Income and Its Impact on Agriculture: Evidence from Albania." Agricultural Economics 40(2): 139-60.

Krusekopf, C. C. (2002). "Diversity in Land-Tenure Arrangements under the Household Responsibility System in China." China Economic Review 13(2-3): 297-312.

Kung, J. K. and S. Liu (1997). "Farmers' Preferences Regarding Ownership and Land Tenure in Post-Mao China: Unexpected Evidence from Eight Counties " The China Journal 38: 33-63.

Kung, J. K. (2002). "Off-Farm Labor Markets and the Emergence of Land Rental Markets in Rural China." Journal of Comparative Economics 30(2): 395-414.

Laine, T. and M. Gasser (2003). "How Communicative Pressure Affects Phonology: Modeling Sound Change in a Population of Communicators." Presentation in the 8th International Cognitive Linguistics Conference. Logrono, Spain.

Lanjouw, P., J. Quizon, and R. Sparrow (2001). "Non-Agricultural Earnings in Peri-Urban Areas of Tanzania: Evidence from Household Survey Data." Food Policy 26(4): 385-403.

Lauby, J and O. Stark (1988). "Individual Migration as a Family Strategy: Young Women in the Philippines." Population Studies, 42(3): 473-86.

Le, K. T. (2010). "Separation Hypothesis Tests in the Agricultural Household Model." American Journal of Agricultural Economics 92(5): 1420-31.

Lee, C. K. C. and S. E. Beatty (2002). "Family Structure and Influence in Family Decision Making." The Journal of Consumer Marketing 19(1): 24-41.

Li, B. (2006). "Floating Population or Urban Citizens? Status, Social Provision and Circumstances of Rural–Urban Migrants in China." Social Policy & Administration 40(2): 174-95.

Li, G., Rozelle, S., and Brandt, L. (1998). "Tenure, Land Rights, and Farmer Investment Incentives in China."Agricultural Economics 19(1-2): 63-71.

Li, J. and Y. Yao (2002). "Egalitarian Land Distribution and Labor Migration in Rural China." Land Reform, Land Settlement and Cooperatives FAO (1): 80-91.

Li, W. and Y. Li (1995). "Spatial Characteristics of China's Interprovincial Migration." Geographic Analysis 27(2):137-51.

Liang, Z. and Z. Ma (2004). "China's Floating Population: New Evidence from the 2000 Census." Population and Development Review 30(3): 467-88.

Lin, J. Y. (1992). "Rural Reforms and Agricultural Growth in China." The American Economic Review 82(1): 34-51.

Lin, J. Y. (1994). "Impact of Hybrid Rice on Input Demand and Productivity." Agricultural Economics 10(2): 153-64.

Lin, J. Y. (1995). "Endowments, Technology, and Factor Markets: A Natural Experiment of Induced Institutional Innovation from China's Rural Reform." American Journal of Agricultural Economics 77(2): 231-42.

Lise, J. and Seitz, S. (2004). "Consumption Inequality and Intra-Household Allocations." Queens IER Working Paper.

Lohmar, B. (2001). "Changes in Labor, Land, and Credit Markets Lead China's Farmers on the Path toward Modernization." In: H. Hsu and F. Gale (Eds.) China Agriculture in Transition/WRS -012, Economic Research Service, USDA: 9-12.

Lopez, R.E. (1984). "Estimating Labor Supply and Production Decisions of Self-Employed Farm Producers." European Economic Review 24: 61-82.

Lopez, R. E. (1986). "Structural Models of the Farm Household That Allow for Inter-dependent Utility and Profit-Maximization Decisions'" In: I.J. Singh, L. Squire, and J. Strauss (Eds.) Agricultural Household Models: Extensions, Applications, and Policy. Baltimore, MD: Johns Hopkins University Press.

Luke S. and L. Spector (1996). "Evolving Teamwork and Coordination with Genetic Programming." In: J. R. Koza, D. E. Goldberg, David B. Fogel, and Rick L. Riolo (Eds.) Genetic Programming: Proceedings of the First Annual Conference, Cambridge, MA: MIT Press.

Lundberg, S. J., R. A. Pollak and T. J. Wales (1997). "Do Husbands and Wives Pool Their Resources? Evidence from the United Kingdom Child Benefit." The Journal of Human Resources 32(3): 463-80.

Lynch. J. P. (2007). "Roots of the Second Green Revolution." Australian Journal of Botany 55(14): 493-512.

Makowsky M., J. Tavares, T. Makany, and P. Meier (2006). "An Agent-based Model of Crisis-Driven Migration." Proceedings of the Complex Systems Summer School, Santa Fe Institute, New Mexico.
http://www.santafe.edu/events/workshops/images/6/67/Sf_csss06_makowsky_et_al.pdf

Manser, M. and M. Brown (1980). "Marriage and Household Decision-Making: A Bargaining Analysis." International Economic Review 21(1): 31-44.

Massey, D. S., J. Arango, G. Hugo, A. Kouaouci, A. Pellegrino, and J. E.Taylor (1993). "Theories of International Migration: A Review and Appraisal." Population and Development Review 19(3): 431-66.

Mazumdar, D. (1976). "The Rural-Urban Wage Gap, Migration, and the Shadow Wage." Oxford Economic Papers 28(3): 406-25.

McElroy, M. B. and M. J. Horney (1981). “Nash-Bargained Household Decisions: Toward a Generalization of the Theory of Demand.” International Economic Review 22(2): 333-49.

McKenzie, D. and H. Rapoport (2007). "Network Effects and the Dynamics of Migration and Inequality: Theory and Evidence from Mexico." Journal of Development Economics 84(1): 1-24.

Mendola, M. (2008). "Migration and Technological Change in Rural Households: Complements or Substitutes?" Journal of Development Economics 85(1-2): 150-75.

Menczer, F. and R. K. Belew (1996). "From Complex Environments to Complex Behaviors." Adaptive Behavior 4(4): 317-63.

Messina, M. J. (1999). "Legumes and Soybeans: Overview of Their Nutritional Profiles and Health Effects." The American Journal of Clinical Nutrition 70(3): 439-50.

Mincer, J. (1977). "Family Migration Decisions." Journal of Political Economy 86(5): 749-73.

Moffat, J. (2000). "Representing the Command and Control Process in Simulation Models of Conflict." The Journal of the Operational Research Society 51(4): 431-39.

Moss, S. (2008). "Alternative Approaches to the Empirical Validation of Agent-Based Models." Journal of Artificial Societies and Social Simulation 11(15) http://jasss.soc.surrey.ac.uk/11/1/5.html.

National Bureau of Statistics of China: http://www.stats.gov.cn/tjsj/pcsj/

Niroula, G. S. and G. Thapa (2005). "Impacts and Causes of Land Fragmentation, and Lessons Learned from Land Consolidation in South Asia." Land Use Policy 22(4): 358-72.

Otsuka, K., H. Chuma and Y. Hayami (1992). "Land and Labor Contracts in Agrarian Economies: Theories and Facts." Journal of Economic Literature 30(4): 1965-2018.

Otsuka, K. and K. P. Kalirajan (2006). "Rice Green Revolution in Asia and its Transferability to Africa: An Introduction." The Developing Economies 44(2): 107-22.

Otsuka, K. and T. Yamano (2006). "Introduction to the Special Issue on the Role of Nonfarm Income in Poverty Reduction: Evidence from Asia and East Africa." Agricultural Economics 35(3): 393-97.

Otter, H. S., A. van der Veen, and H.J. Vriend (2001). "ABLOoM: Location Behaviour, Spatial Patterns, and Agent-Based Modeling." Journal of Artificial Societies and Social Simulation 4(4) http://www.soc.surrey.ac.uk/JASSS/4/4/2.html

Park, A. (2004). “Rural-Urban Inequality in China.” Prepared for the Eleventh Five-Year Plan of China.World Bank,Washington, DC.

Parker, D. C. and V. Meretsky (2004). "Measuring Pattern Outcomes in an Agent-Based Model of Edge-Effect Externalities Using Spatial Metrics." Agriculture, Ecosystems & Environment 101(2-3): 233-50.

Peffer G. and B. Llacay (2007). "Higher-Order Simulations: Strategic Investment under Model-Induced Price Patterns." Journal of Artificial Societies and Social Simulation 10(2): 6-23.

Ping, H and F. N. Pieke (2003). "China Migration Country Study." Paper presented at the Regional Conference on Migration, Development and Pro-Poor Policy Choices in Asia. Dhaka, Bangladesh.

Plantinga, A. J. (1996). "The Effect of Agricultural Policies on Land Use and Environmental Quality." American Journal of Agricultural Economics 78(4): 1082-91.

Poston, D. L. and C. C. Duan (2000). "The Current and Projected Distribution of the Elderly and Eldercare in the People's Republic of China." Journal of Family Issues 21(6): 714-32.

Rapoport, B., C. Sofer, and A. Solaz (2009). “Household Production in a Collective Model: Some New Results,” Journal of Population Economics 24(1): 23-45.

Ravallion, M. and S. Chen (2007). "China's (Uneven) Progress against Poverty." Journal of Development Economics 82(1): 1-42.

Poncet, S. (2006). "Provincial Migration Dynamics in China: Borders, Costs and Economic Motivations." Regional Science and Urban Economics 36(3): 385-98.

Rozelle, S., J. E. Taylor, and A. de Brauw (1999). "Migration, Remittances, and Agricultural Productivity in China." The American Economic Review 89(2): 287-91.

Reynolds, C. W. (1987). "Flocks, Herds and Schools: A Distributed Behavioral Model." ACM SIGGRAPH Computer Graphics 21(4): 25-34.

Rosegrant, M. W. and P. L. Pingali (1994). "Policy and Technology for Rice Productivity Growth in Asia." Journal of International Development 6(6): 665-88.

Ruben, R. and M. Van den berg (2001). "Nonfarm Employment and Poverty Alleviation of Rural Farm Households in Honduras." World Development 29(3): 549-60.

Sasaki Y. and P. Box (2003). "Agent-Based Verification of von Thünen's Location Theory." Journal of Artificial Societies and Social Simulation 6(2) http://jasss.soc.surrey.ac.uk/6/2/9.html

Schreinemachers, P and T. Berger (2006). "Land Use Decisions in Developing Countries and Their Representation in Multi-Agent Systems." Journal of Land Use Science 1(1): 1-16.

Seeborg, M. C., Z. Jin and Y. Zhu (2000). "The New Rural-Urban Labor Mobility in China: Causes and Implications." The Journal of Socio-Economics 29(1): 39-56.

Shi, T. (2002). "Ecological Agriculture in China: Bridging the Gap between Rhetoric and Practice of Sustainability." Ecological Economics 42(3): 359-68.

Silveira, J. J., A. L. Espindola, T. J. P. Penna (2006). "Agent-Based Model to Rural-Urban Migration Analysis." Physica A: Statistical Mechanics and its Applications 364: 445-56.

Skoufias, E. (1994). "Using Shadow Wages to Estimate Labor Supply of Agricultural Households." American Journal of Agricultural Economics 76(2): 215-27.

Skyrms, B. and U. C. Irvine (2001). "The Stag Hunt." Proceedings and Addresses of the American Philosophical Association 75(2): 31-41.

Smil, V. (1999). "China's Agricultural Land." The China Quarterly 158: 414-29.

Song, Y., L. Zhang, D. Sun, Q. Sun and J. Jiggins (2009). "Feminization of Agriculture in Rapid Changing Rural China: Policy Implication and Alternatives for an Equitable Growth and Sustainable Development." Paper presented at the FAO-IFAD-ILO Workshop on Gaps, Trends and Current Research in Gender Dimensions of Agricultural and Rural Employment: Differentiated Pathways out of Poverty. Rome, Italy.

Soule, M. J., A. Tegene and K. D. Wiebe (2000). "Land Tenure and the Adoption of Conservation Practices." American Journal of Agricultural Economics 82(4): 993-1005.

Stark, O. and D. E. Bloom (1985). "The New Economics of Labor Migration." The American Economic Review 75(2): 173-78.

Stark, O. and R. Lucas (1988). "Migration, Remittances, and the Family." Economic Development and Cultural Change 36(3): 465-81.

Stark, O. and Y. Q. Wang (2000). "A Theory of Migration as a Response to Relative Deprivation." German Economic Review 1(2): 131-43.

Stauss, J. (1986). "The Theory and Comparative Statics of Agricultural Household Models: A General Approach?" In: I. J. Singh, L. Squire, and J. Strauss (Eds.) Agricultural Household Models: Extensions, Applications, and Policy. Baltimore, MD: Johns Hopkins University Press.

Stiglitz, J. E. (2002). "Information and the Change in the Paradigm in Economics." The American Economic Review 92(3):460-501.

Takadama, K., T. Kawai and Y Koyama (2008). "Micro- and Macro-Level Validation in Agent-Based Simulation: Reproduction of Human-Like Behaviors and Thinking in a Sequential Bargaining Game." Journal of Artificial Societies and Social Simulation 11(29). *http://jasss.soc.surrey.ac.uk/11/2/9/9.pdf*

Tan, S., N. Heerink and F. Qu (2006). "Land Fragmentation and its Driving Forces in China." Land Use Policy 23(3): 272-85.

Taylor, J. E., J. Arango, G. Hugo, A. Kouaouci, D. S. Massey and A. Pellegrino (1996). "International Migration and Community Development." Population Index 62(3): 397-418.

Taylor, J. E. (1999). "The New Economics of Labour Migration and the Role of Remittances in the Migration Process." International Migration 37(1): 63-88.

Taylor, J. E., S. Rozelle and A. de Brown (2003). "Migration and Incomes in Source Communities: A New Economics of Migration Perspective from China." Economic Development and Cultural Change 52(1): 75-101.

Tesfatsion, L. (2002). "Agent-Based Computational Economics: Growing Economies From the Bottom Up." Artificial Life 8(1): 55-82.

Tikabo, M. and S. Holden (2007). "Factor Market Imperfections and Land Rental Market in the Highlands of Eritrea: Theory and Evidence." Department of Agricultural Economics. Agricultural University of Norway. Revised for Land Economics.

Tilman, D. (1998). "The Greening of the Green Revolution." Nature 396: 211-12.

Todaro, M. P. (1969). "A Model of Labor Migration and Urban Unemployment in Less Developed Countries." The American Economic Review 59(1): 138-48.

Todaro, M. P. (1976). "Urban Job Expansion, Induced Migration and Rising Unemployment: A Formulation and Simplified Empirical Test for LDCs." Journal of Development Economics 3(3): 211-25.

Turner, M. A., L. Brandt, and S. Rozelle (2002). "Property Rights Formation and the Organization of Exchange and Production in Rural China." University of Toronto, Department of Economics Working Paper.

Udry, C. (1996). "Gender, Agricultural Production, and the Theory of the Household." The Journal of Political Economy 104(5): 1010-46.

United Nation Population Fund (UNFPA) 2007 Report http://www.unfpa.org/swp/2007/presskit/pdf/sowp2007_eng.pdf

Van Soest, A. (1995). "Structural Models of Family Labor Supply: A Discrete Choice Approach." The Journal of Human Resources 30(1): 63-94.

Vermeulen, F. (2002). "Collective Household Models: Principles and Main Results." Journal of Economic Surveys 16(4): 533-64.

Vermeulen, F. (2006). "A Collective Model for Female Labour Supply with Non-participation and Taxation." Journal of Population Economics 19(1): 99-118.

Wang, K. C., A.-T. Hsieh, Y.-C. Yeh and C.-W. Tsai (2004). "Who is the Decision-Maker: The Parents or the Child in Group Package Tours?" Tourism Management 25(2): 183-94.

Wei, Y. (1997). "Interregional Migration in Socialist Countries: The Case of China." Geojournal 41: 405-512.

Weinstein, B. L. (1996). "Developing China's Hinterland: From Autarky to Anarchy?" Challenge 39(2): 55-9.

Winters, P., T. E., Alberto Zezza, Benjamin Davis, Calogero Carletto (2010). "Patterns of Rural Development: A Cross-Country Comparison using Microeconomic Data." Journal of Agricultural Economics 61(3): 628-51.

Xintian County 2004 Economy Growth Report http://www.glzy8.com/show/d4a6ef4f14ca51f1.html

Wong, S. C., X. D. Li, G. Zhang, S. H. Qi, and Y. S. Min (2002). "Heavy Metals in Agricultural Soils of the Pearl River Delta, South China." Environmental Pollution 119(1): 33-44.

Wouterse, F. and J. E. Taylor (2008). "Migration and Income Diversification: Evidence from Burkina Faso." World Development 36(4): 625-40.

Yan, X., H. Liao, S. Beebe, M. Blair, and J. Lynch (2004). "QTL Mapping of Root Hair and Acid Exudation Traits and Their Relationship to Phosphorus Uptake in Common Bean." Plant and Soil 265(1): 17-29.

Yang, D. T. (1997). "China's Land Arrangements and Rural Labor Mobility." China Economic Review 8(2): 101-15.

Yang, D. T. (2004). "Education and Allocative Efficiency: Household Income Growth during Rural Reforms in China." Journal of Development Economics 74(1): 137-62.

Yao, Y. (2000). "The Development of the Land Lease Market in Rural China." Land Economics 76(2): 252-66.

Zeng, Y. and J. W. Vaupel (1989). "The Impact of Urbanization and Delayed Childbearing on Population Growth and Aging in China." Population and Development Review 15(3): 425-45.

Zhai, F. and Z. Wang (2002). "WTO Accession, Rural Labour Migration and Urban Unemployment in China." Urban Studies 39(12): 2199-217.

Zhai, F. and T. Hertel (2003). “Labor Market Distortions, Rural-urban Inequality and the Opening of China’s Economy.” GTAP Working Paper 3455. World Bank, Washington, DC.

Zhang, K. H. and S. Song (2003). "Rural-Urban Migration and Urbanization in China: Evidence from Time-Series and Cross-Section Analyses." China Economic Review 14(4): 386-400.

Zhang, J., M. Kuwano, B. Lee and A. Fujiwara (2009). "Modeling Household Discrete Choice Behavior Incorporating Heterogeneous Group Decision-Making Mechanisms." Transportation Research. Part E, Logistics and Transportation Review 43(2): 230-50.

Zhao, Y. (1999). "Leaving the Countryside: Rural-To-Urban Migration Decisions in China." American Economic Association 89(2): 281-86.

Zhao, Y. (2002). "Causes and Consequences of Return Migration: Recent Evidence from China." Journal of Comparative Economics 30(2): 376-94.

Zheng, S., F. Long, C. Fan and Y. Gu (2009). "Urban Villages in China: A 2008 Survey of Migrant Settlements in Beijing." Eurasian Geography and Economics 50(4): 425-46.

Zhu, N. (2002). "The Impacts of Income Gaps on Migration Decisions in China." China Economic Review 13(2): 213-30.

Zhu, R. (2010). "The Gender Wage Differentials among Rural-Urban Migrants in China." Ecoledeconomiedeparis.fr Working paper : *http://www.ecoledeconomiedeparis.fr/IMG/pdf/Rong_ZHU_The_Gender_Wage_Differentials_among_Rural-Urban_Migrants_in_China.pdf*

Zuo, J. (2004). "Feminization of Agriculture, Relational Exchange, and Perceived Fairness in China: A Case in Guangxi Province." Rural Sociology 69(4): 510-31.

Appendix A

Appendix Table A.1. 2005-2006 labor statistics: Migrant labor sex ratio (male/population) by county by age categories (unit: person)

Age categories		Longan County	Laibin County	Lingchuan County	Xintian County	Yingde County
15-19	Male	16,080	29,444	17,363	23,228	37,130
	Female	11,247	23,868	13,347	20,324	28,829
	Ratio	0.588	0.552	0.565	0.533	0.563
20-24	Male	11,519	18,479	10,440	12,076	20,650
	Female	8,218	17,837	8,120	10,700	17,286
	Ratio	0.584	0.509	0.563	0.530	0.544
25-29	Male	13,904	19,889	12,985	13,201	29,574
	Female	11,411	20,895	11,882	12,204	28,023
	Ratio	0.549	0.488	0.522	0.520	0.513
30-34	Male	16,332	23,867	15,864	16,304	36,693
	Female	13,283	23,790	14,786	15,828	35,372
	Ratio	0.551	0.501	0.518	0.507	0.509
35-39	Male	14,766	27,245	15,627	17,029	36,724
	Female	12,279	26,187	14,218	15,602	33,586
	Ratio	0.546	0.510	0.524	0.522	0.522
40-44	Male	9,700	25,120	11,721	13,183	27,307
	Female	8,686	24,254	10,899	12,081	23,733
	Ratio	0.528	0.509	0.518	0.522	0.535
45-49	Male	10,082	18,652	13,666	11,628	23,521
	Female	9,274	17,920	12,318	10,701	20,350
	Ratio	0.521	0.510	0.526	0.521	0.536
50-54	Male	7,763	19,951	9,481	8,652	17,216
	Female	7,445	19,089	8,001	7,706	14,585
	Ratio	0.510	0.511	0.542	0.529	0.541
55-59	Male	6,615	15,657	6,386	5,991	14,488
	Female	6,885	14,492	5,637	5,576	13,697
	Ratio	0.490	0.519	0.531	0.518	0.514
60-64	Male	6,057	12,679	6,101	6,491	14383
	Female	6,156	12,128	5,666	6,148	14302
	Ratio	0.496	0.511	0.518	0.514	0.501
65-69	Male	4,738	10,790	5,481	4,831	12,525
	Female	5,396	10,429	5,564	4,681	13,863
	Ratio	0.468	0.509	0.496	0.508	0.475

(Source: National Bureau of Statistics of China)

Appendix B

Decision-making questions from baseline survey

I. Consumption

1. Who decides what food to purchase?
2. Who decides what to have for dinner?

II. Production

3. Who decides which crops to grow?
4. Who decides whether to grow soybeans or not?
5. Who decides which livestock to keep?
6. Who decides what to feed livestock?
7. Who decides the amount of fertilizer to use?
8. Who decides the amount of pesticide or herbicides to use?
9. Who decides whether to purchase farm equipment or not?

III. Marketing

10. Who decides how and where to market crops?
11. Who decides how and where to market livestock?

IV. Innovation

12. Who decides whether to adopt new crop cultivars or not?
13. Who decides whether to try new ideas on the farm or not?
14. Who decides whether to try new ideas at home or not?
15. Who decides whether to engage in contract farming or not?

Appendix C

Appendix C.1. Summary of household decision-making responses in number responding in each category

	Husband	Wife	Both husband & wife	Adult males	Adult females	All adults	Sum
Household food consumption	23	56	46	7	10	14	156
Household food to purchase	32	45	49	7	8	15	156
Crop types	45	37	52	10	6	6	156
Soybean production	46	37	53	10	5	5	156
Livestock types	29	52	55	8	7	5	156
Livestock feed	31	59	46	7	8	5	156
Fertilizer usage	57	31	48	10	7	3	156
Pesticide/herbicides usage	56	32	47	12	6	3	156
Purchase farm equipment	62	18	54	10	5	7	156
Market crops	50	34	48	14	6	4	156
Market livestock	51	32	51	11	6	5	156
Contract farming	62	19	53	10	5	7	156
New crop cultivars adoption	44	37	53	10	6	6	156
Try new ideas on farm	55	25	56	11	5	4	156
Try new ideas at home	59	23	51	12	5	6	156

Appendix D

Summary of Durbin-Wu-Hausman test results for determining the potential endogeneity of the sharing rule in intrahousehold decision-making structure

Household food consumption	F(1, 136) = 0.06	Prob > F = 0.8101
Household food to purchase	F(1, 136) = 0.00	Prob > F = 0.9520
Crop types	F(1, 136) = 1.45	Prob > F = 0.2306
Soybean production	F(1, 136) = 0.01	Prob > F = 0.9289
Livestock type	F(1, 136) = 0.08	Prob > F = 0.7736
Livestock feed	F(1, 136) = 0.08	Prob > F = 0.7734
Fertilizer usage	F(1, 136) = 0.02	Prob > F = 0.8750
Pesticide/herbicide usage	F(1, 136) = 0.03	Prob > F = 0.8605
Purchase farm equipment	F(1, 136) = 0.41	Prob > F = 0.5238
Market crops	F(1, 136) = 0.04	Prob > F = 0.8420
Market livestock	F(1, 136) = 0.17	Prob > F = 0.6773
Contract farming	F(1, 136) = 0.28	Prob > F = 0.6007
New crop cultivars adoption	F(1, 136) = 0.01	Prob > F = 0.9371
Try new ideas on farm	F(1, 136) = 0.08	Prob > F = 0.7733
Try new ideas at home	F(1, 136) = 0.19	Prob > F = 0.6616

VITA

Lin Zhang

Academics

- ***Ph.D. Agricultural, Environmental and Regional Economics, Ph.D. Dual Title Degree in Operations Research***, Pennsylvania State University, USA, 2004-2011
- ***M.Sc. Environmental Economics***, Wageningen University, the Netherlands, 2001-2003
- ***B.A. Land Resource Management***, China Agricultural University, China, 1997- 2001

Professional Experience

- Course Instructor, Pennsylvania State University, 2011
- Adjunct Professor, Susquehanna University, 2009
- Teaching Assistant, Pennsylvania State University, 2008-2009
- Research Assistant, Pennsylvania State University, 2004-2008
- Research Assistant, Wageningen University, 2002-2003

Awards

- Agricultural and Applied Economics Association (AAEA) Young Professional and Graduate Student Travel Grant, AAEA, 2010
- College of Agricultural Sciences Graduate Student Travel Grant, Pennsylvania State University, 2010
- Thomas C. and Jackie M. Floore Memorial Scholarship, Pennsylvania State University, 2008
- Doctoral Student Competitive Grant, College of Agricultural Sciences, Pennsylvania State University, 2007
- McKnight Foundation Scholarship, Pennsylvania State University, 2004-2008

Selected Professional Papers and Presentations

- Zhang, L. and J. L. Findeis. 2010. "Intra-Household Time Allocation and Labor Migration Decisions in Rural South China". Agricultural and Applied Economics Association (AAEA) Annual Conference, Denver, Colorado.

- Zhang, L. and J. L. Findeis. 2008. "A Multi-agent System (MAS) Model of Agricultural Technology Adoption, Labor Mobility and Land Markets." INFORMS (Institute for Operations Research and Management Systems) Annual Conference, Washington, DC.

- Zhang, L. and J.L. Findeis. 2007. "Agent-based Modeling of Household Migration and Land Use Decisions in South China." Paper presented at the Transatlantic Land Use Change Conference, Washington, DC.

- Zhang, L. and J.L. Findeis. 2007. "Socio-Economic Study of Soybean Production in South China." Presented at the McKnight Foundation Cornell Meeting. Cornell University, Ithaca, New York.