CHILD LABOR AND AGRICULTURAL PRODUCTION IN NORTHERN MALI

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This dissertation examines how agricultural households allocate children's time between work and schooling activities and utilize access to production technology, namely irrigation, to assure minimum subsistence requirements in an arid and famine-prone region of northern Mali. These questions are examined using a data set that the author collected which tracked 245 households in 2006 from a previous survey conducted in 1997-98 and a larger cross-sectional survey of 2,658 households that was collected in 151 villages across two regions of Mali (Tombouctou and Gao). The second chapter of the dissertation provides descriptive statistics from the sample and an explanation of the survey methodology.

The third and fourth chapters investigate children's time allocation to schooling, home production, and market production using participation and hours data. Two types of shocks to the household's agricultural income and total labor availability provide plausibly exogenous variation to identify substitution effects across children's activities including withdrawal from school and adult labor supply. These results are robust to varying assumptions about the structure of unobserved heterogeneity at the household and village level. The role of different asset types on child labor substitution between activities when households experience shocks is also investigated. Because the collection of children's time allocation information from household surveys is prone to significant sources of measurement error, the fourth

chapter also compares hours data and subjective measures of children's work obtained through a game played with children.

The fifth chapter investigates the impact of village level irrigation projects on various household welfare indicators. Using difference-in-differences, propensity score matching, and matched difference-in-differences with an eight year panel, the impact of access to irrigation on poverty, agricultural production, and nutrient intakes is estimated. This chapter also provides evidence of both saving and sharing within villages as an alternative strategy to consuming gains in agricultural production. This finding suggests that estimating program impact using consumption data may underestimate the welfare gains of irrigation investment by ignoring the household's saving and informal insurance network.

BIOGRAPHICAL SKETCH

Andrew Scott Dillon was born in Woodbridge, VA in 1977. He completed his undergraduate studies at the University of Virginia in Economics and an interdisciplinary program, Political and Social Thought in 1999. After finishing these studies, he served as a Peace Corps Volunteer in Mali from 1999-2001, before beginning his graduate work at Cornell.

To Karin, for courage

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 2

Chapter 3

Chapter 4

Chapter 5

LIST OF ABBREVIATIONS

CSCOM	Centre de Santé Communitaire (Community Health Center)
IFAD/FIDA	International Fund for Agricultural Development/ Fonds International pour le Développment Agricole
IFPRI	International Food Policy Research Institute
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
KfW	Kreditanstalt für Wiederbau
PDZL II	Projet de Développment Zone Lacustre-Phase II
PIV	Périmètre Irrigues Villageois (Village Irrigation Project)
SAGA	Strategies and Analysis for Growth and Access

CHAPTER 1: INTRODUCTION

This dissertation examines two topics in development economics, child labor and agricultural production in Northern Mali, where little data exists in an arid and inhospitable region that is at the frontier of the Saharan desert. This region has been labeled, "*le Mali inutile*", by development agencies and as a result received little national or international attention until civil conflict broke out in the 1990's partially as a result of these policies. It is for this reason that topics such as child labor and agricultural production are interesting to test in such a place of extreme poverty, high transportation costs, few formal financial institutions, and forbidding agro-ecological conditions where household responses to shocks or access to technology would produce strong responses in the household's welfare.

In such resource scarce environments, the allocation of children between schooling and work represents for the household a tradeoff between meeting subsistence requirements today and investing in children's human capital for higher future earnings. How is children's time allocated within agricultural households across household production, market production and schooling activities? What do different types of production and health shocks reveal about labor allocation within the household? What are the roles of different types of assets in insuring children against increased work in the face of shocks? These questions address internal human resource allocation questions, but households also face decisions with respect to externally provided technologies, namely irrigation, that expand the household's production possibilities set. The potential linkages between access to irrigation, household consumption, and nutrition underscore the importance of how households appropriate the benefits of an increased agricultural production set that has implications on the current household welfare through increased nutrient intakes or asset accumulation and future welfare such as increased child labor or changes in household composition. How effective is irrigation technology in improving household consumption, nutrient intake and agricultural production? Does access to irrigation alter household saving or informal village insurance networks?

To address these two research topics, I collected household data that tracked 245 households in 2006 from a previous survey conducted in 1997-98 and a larger cross-section of 2,658 that was collected in six states (*cercles*) of Mali (Niafunke, Dire, Goundam, Tombouctou, Rharous, and Bourem). The survey methodology, sampling, and questionnaire design are described in chapter two. Descriptive statistics and a regional description are also provided to aid in the interpretation of the sample and the inferences that I draw from in subsequent chapters.

Chapters three and four in this dissertation examine children's participation and time allocation to domestic tasks, market-oriented tasks and schooling. In chapter three, "Child Labor and Schooling Responses to Production and Health Shocks," production shocks from harvest period pest infestations induce households to withdraw children from school and increase the probability they are selected into farm work. Health shocks to women increases the probability a child participates in the family business and child care activities. These results are robust to varying assumptions about the structure of unobserved heterogeneity at the household and village level. Different measures of household assets are also constructed to test whether assets serve as a buffer against increased child labor in response to shocks. Assets such as livestock have mixed effects on child labor and schooling, depending on the shock and asset type. However, household durables are substitutes for increased child labor when household face production shocks.

The fourth chapter in this dissertation, “Changes in the Distribution of Children’s Time in Response to Production and Health Shocks” analyzes evidence from hours data and the subjective evaluations by children. The collection of children’s time allocation information from household surveys is prone to significant sources of measurement error due to recall error and proxy respondent bias. This paper compares hours data and a subjective time allocation module with children as the respondents to elicit their relative time allocation across school, work and leisure time. Using the hours data, conditional labor and schooling functions are specified in both an equation by equation random effects specification and a specification that permits cross equation correlation between work and schooling activities. Ordered probit models are estimated using the outcomes of the child’s subjective module to determine the consistency of the outcome variables, controlling for household and community covariates. The marginal effects of changes in the intensity of children’s work and schooling as a response to production and health shocks are also estimated using the hours and subjective welfare measures of children’s time allocation.

The fifth chapter in this dissertation, “Access to Irrigation and the Escape from Poverty” presents evidence on the impact of village level irrigation projects on household welfare. Significant changes in the agricultural sector in northern Mali suggest a large contribution of irrigation to welfare increases over the past 8 years. Using differences in differences, propensity score matching, and matched differences in differences with a small panel, the impact of access to irrigation on poverty, production, and nutrient intakes are estimated. These findings suggest that gains in agricultural production value do not transfer uniquely to household consumption. Two alternative hypotheses are tested; the gains in agricultural production induced by irrigation yield higher household saving or intra-village transfers from irrigators to non-irrigators contribute to informal social insurance. The paper provides evidence of both saving and sharing within villages as an alternative strategy to consuming gains in agricultural production. This finding suggests that estimating program impact using consumption per capita may underestimate the welfare gains of irrigation investment by ignoring the household's saving and informal insurance network.

The final chapter of the dissertation provides a summary of the research results and a reflection on their implications.

CHAPTER 2: METHODOLOGY AND DESCRIPTIVE STATISTICS: *ETUDE SUR LA PAUVRETE ET LA SECURITE ALIMENTAIRE AU NORD MALI 2006*

I: Introduction

The data used in this dissertation was collected as part of the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006* that is a representative multi-topic household of 2,658 households in Northern Mali. The survey was undertaken from February 2006 to November 2006 in six *cercles*[1] (Niafunke, Dire, Goundam, Tombouctou, Rharous, Bourem) in the regions of Tombouctou and Gao. Of the 2,658 households in the sample, 245 households in the *commune* of Soboundou, Niafunke that were originally surveyed in a similar study conducted in 1997-98[2], were resurveyed twice in 2006. These households were resurveyed in February/March and August/September to correspond with the periods under which the 1997-98 survey was undertaken. In this sense, there is both a panel and a cross section component of the data set.

This chapter has two primary objectives. The first objective is to describe the survey methodology and the program of research undertaken. The second section of this chapter describes the survey objectives, survey area, the survey design and sample

[1] Administratively, Mali is divided into eight regions that are composed of several *cercles* each. A *cercle* contains multiple communes. The *cercle* is analogous to a state or province, while the commune is analogous to a county or district.

[2] These data, originally collected by Luc Christiaensen with support from John Hoddinott have been made available by the International Food Policy Research Institute. Funding for data collection was provided by the International Fund for Agricultural Development (TA Grant No. 301-IFPRI) and USAID/Mali (TA Grant No. 301-IFPRI). Neither IFAD nor USAID are responsible for any errors in these data or in their interpretation. These data could not have been collected without the substantial assistance of Sidi Guindo,
Abdourhamane Maiga and Mamadou Nadio, and the helpful cooperation of the residents of the Zone Lacustre.

selection, as well as the survey implementation. The second objective is to outline some of the basic descriptive statistics that the survey has produced. This will provide a general context for the analysis undertaken in Chapters 3, 4 and 5 of the dissertation. Sections three, four and five in this chapter provide basic analysis of household demographics, consumption, income and livelihood activities, agricultural production and poverty analysis.

II: Survey Area Description

The survey area of the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006* is composed of 2 regions (Tombouctou and Gao) from which 151 villages, nomadic *fractions* or towns in 6 *cercles* (Niafunke, Goundam, Dire, Tombouctou, Rharous, and Bourem) were randomly selected to participate in the study. The Saharan zone (desert or arid region) receives less than 150 mm of rainfall par annum. This varies starkly with the Sahelien zone (grassland or semi-arid region) which receives 200-600 mm par annum and the south of Mali which can receive between 600-1200 mm par annum (FIDA 1996). The dominant ecological resource in the region is the Niger River that serves as a source of water for agriculture and animal husbandry. The inner Niger Delta is a rich agricultural resource in which flooding from the Niger augments water levels in temporary and permanent lakes and ponds, as well as smaller streams and tributaries. This diversity of water resources is harnessed by farmers through motorized pump irrigation, water-recession agriculture around lakes and streams and in the Niger River itself. Rain-fed agriculture which does not depend on the water levels of the Niger River is also extensively practiced. There is one primary agricultural season with a limited secondary agricultural season. The secondary agricultural season is limited by the dearth of rainfall, the recession of the

Niger River, and the arid heat which begins at the end of January lasting until April or May. Herders benefit greatly from the temporary and permanent lakes which provide water and pasture for cattle and sheep. Fishing is also an important economic activity which capitalizes on the Niger River and its tributaries to supplement the income and diets of households along its banks.

Figure 2.1: Map of Mali

Data Source: Intute, Science, engineering and Technology, “Mali: Geography and Maps,” Intute, http://www.intute.ac.uk/sciences/worldguide/html/951_map.html#map2 (accessed December 3, 2007).

The population in northern Mali is highly clustered around water sources, but sparsely distributed over the total area within the regions of Tombouctou and Gao. Northern Mali has an estimated population of 809,111 people that live in an area bordered to the north by the Sahara Desert. In 1998, the administrative population for the regions of Kidal, Gao and Tombouctou were 27,521; 335,976; and 445,614, respectively (Cartographie du Mali 2001). Population density is increasingly concentrated around these water resources, so that regional population density statistics may be deceptive indicators of natural resource pressure from the population. Statistics for northern Mali indicate 1.5 people per km^2, while in the south of Mali, the density reaches 17 people per km^2 (FIDA 1996).

The population of northern Mali is ethnically diverse. Sedentary ethnic groups that primarily practice agriculture include the Songray, Bambara, and the Soninkés. The Peulh, Tamasheq, Berabich and Maures are traditionally transhumant pastoralists, though increasingly are becoming sedentarized, especially in the region of Tombouctou. Lastly, the Sorko, Korongoy, and Bozo derive their livelihood from fishing and transport activities along the Niger River.

Poverty is a widespread phenomenon in Mali in general, but specifically in the rural regions of northern Mali. The region has known several significant economic shocks including widespread drought and famine in 1914, 1973 and 1984, as well as a civil conflict which destabilized the region from 1990-1996. The Government of Mali's *Poverty Reduction Strategy Paper 2002* reports a national poverty rate of 63.8% with severe poverty in the country at the 21% level. Indicators from the *Rapport National 2003 sur le développement humain durable au Mali* (RNDH 2003) illustrate at the commune level the entrenchment of rural poverty in the north as compared to other regions of Mali. The rural entrenchment of poverty at the commune level in the regions of Kidal, Gao, and Tombouctou are often twice those found in Mali's other regions with poverty rates of 67%, 40%, 48% for the three regions.

Human capital indicators for the regions of Tombouctou, Gao and Kidal also illustrate the lack of public infrastructure in the education and health sectors. According to the *Rapport National 2003 sur le développement humain durable au Mali*, 33 % of communes in Tombouctou, 30% in Kidal and 35% of communes in Gao had no access to primary schools in 1998, whereas the percentages for the regions of Kayes (13%), Koulikoro (1%), Sikasso (6%), Segou (4%), and Mopti (7%) were significantly lower indicating better access to primary schools. The population also had little access to health services through community health centers (CSCOMs) in 1998. 94% of communes in Tombouctou, 100% of the communes in Kidal and 91% of the communes of Gao had no access to these community health centers. This compares to the regions of Kayes (73%), Koulikoro (59%), Sikasso (74%), Segou (73%) and Mopti (78%) who also had poor, but slightly lower rates of inaccessibility to CSCOMs by commune.

In addition to differences between the north and south of Mali, there are significant differences between the *cercles* included in the survey. Below is a description of each *cercle* included in the survey.

Niafunké (Region of Tombouctou)

The *cercle* of Niafunke is the westernmost *cercle* in the region of Tombouctou. It borders the regions of Segou to the west and Mopti to its south. Its three major towns

(Niafunke, Lere, and Attara) and smaller villages are scattered around the Niger River and various lakes and streams. Four broad systems of cultivation are practiced in this area which relies on diverse water sources. These include motor pump irrigation (rice), lake recession agriculture (sorghum and corn), rain-fed agriculture (millet), and stream-based agriculture (sorghum). The area of lakes concentrated around Niafunke, often called Zone Lacustre, provides residents arable land for cultivation, but also a zone of grazing areas for pastoralists. The *cercle* of Niafunke has a high concentration of population relative to the other *cercles* mainly because the water resources of the inner Niger delta support multiple livelihood systems and diverse economic activities.

Goundam (Region of Tombouctou)

During the colonial period, the *cercle* of Goundam was a cultural and economic center of importance in northern Mali. However, the majority of Goundam's villages lack access to the Niger River and the complete drying up of Lake Faguibine has caused serious constraints on the *cercle's* agricultural potential. Lake agriculture around the lakes Fati, Horo, and Tele are the primary sources of agricultural production which due to their size permit several crop cycles throughout the year. Pastoralists benefit from the pasture land that is enriched by the major lakes in the *cercle* and seasonal rains. Agricultural villages around Lake Horo, like Guinda Gatta and Echelle, attracted economic and social refugees from Lake Faguibine and other villages affected by the civil conflict in the early 1990s. In addition to agriculture and herding, the town of Tonka has emerged as an important commercial center which is situated strategically between Goundam, Niafunke, and Dire.

Dire (Region of Tombouctou)

The *cercle* of Dire is bordered by Goundam and Tomboctou to its north, Rharous to its east and Niafunke to its west. Dire, like Niafunke, is a *cercle* with agricultural potential since the Niger River and its tributaries extend throughout the communes in the *cercle* when the river levels increase, usually in July or August. Agriculture, fishing and pastoralism are the primary economic activities. Agricultural production is focused on irrigated or floating rice, but wheat has emerged as an important counter-season crop. The city of Dire is a vital commercial center and an important stop for interfluvial commerce.

Tombouctou (Region of Tombouctou)

The city of Tombcoutou serves as the regional administrative and commercial center in the *cercle* of Tombouctou. Most government and non-governmental activity in the region is based in this city, as well as the region's most extensive selection of schools and medical facilities. Extensive commercial activity from trans-Saharian trade as well as a thriving tourist industry augments the traditional agricultural and pastoralist livelihood systems. Large irrigation projects just outside of the town of Tombouctou illustrate the region's rice production potential. However, outside the city of Tombouctou and away from the Niger, the landscape quickly becomes dry and uncultivable. These areas are comprised of transhumant pastoralists in various stages of sedentarization. Access to water remains a serious issue for these communities.

Rharous (Region of Tombouctou)

Rharous is a *cercle* that borders the regions of Tombouctou to its west and the *cercle* of Bourem to its east. It extends south all the way to the Burkina Faso border and finds its limit to the north by the region of Kidal. Primarily a zone of transhumant pastoralism, agriculture is practiced along and in the Niger River as well as several temporary lakes. Access is limited by sand dunes along the river front, so options for linking potentially cultivable land to the river for irrigation purposes are limited. Rharous, relative to other *cercles* in Tombouctou, lacks public infrastructure. Lack of electricity, potable water and passable roads are the *cercle*'s largest problems. Only since September 2006 did cellular phone service ease the demand and high cost of telephone communication.

Bourem (Region of Gao)

The *cercle* of Bourem in the region of Gao is primarily an arid zone that borders the region of Kidal to its north. It is here that the Niger River reaches its northernmost point before descending through Gao and out of Mali into Niger and Nigeria. Bourem shares many of the same problems as Rharous. Lack of electricity and passable roads are serious barriers to its development. Agricultural potential is limited by massive sand dunes that line the Niger River on either side of the river's path. The primary agricultural activities in the region focus on floating rice that is planted along the banks of the river. However, the recent proposal of a hydro-electric dam in the *cercle* may increase the region's agricultural potential and supply of electricity, as well as facilitate the construction of roads that will be needed to access the site for the dam. Seasonal male migration towards Ghana remains a survival strategy which significantly increased as a response to the droughts of the 1970s and 1980s as well as the civil conflict in 1990s.

Kidal (Region of Kidal)

The *cercle* of Kidal borders the regions of Gao to the south, Tombouctou to the west and Algeria to its north. Most of its land lies in the heart of the Sahara desert. Agriculture is very difficult in this region and is found only where gardening projects and wells have been created. Because of these environmental difficulties and a perceived lack of economic development, discontent in Kidal has become a national issue. In addition to being seriously affected by the civil conflict in the 1990s, attacks against government military positions in May 2006 resulted in another negotiated peace settlement, the Accords d'Alger, that complement the Pacte National which was signed in 1992. At the time of this writing, there is no armed conflict, but stability depends on the implementation of the signed agreements. Otherwise, Kidal is an area of trans-Saharan commerce primarily between Algeria and Gao, as well as other trade routes that traverse the desert from the west to east. The opening of a bridge in the city of Gao in September 2006 may increase trans-Saharan trade through Kidal from North Africa.

III: Survey Design and Sample Selection

The survey is designed as a representative two stage cluster sample of households in the *cercles* of Niafunke, Goundam, Dire, Tombouctou, Rharous, and Bourem. Villages, in the rural strata, or quartiers in the urban strata (the clusters) of the sample were randomly selected in the first stage and their population fully enumerated based on households actually residing in the village or quartier during the period of enumeration. The second stage used the lists generated from the first stage to randomly select a list of households to be interviewed[3]. This sample design is commonly used in household surveys and is fully described in Deaton (1997).

In addition to producing a large data set of households across northern Mali, a second objective of the study was to follow up with households originally surveyed in 1997-98 by IFAD, IFPRI, Cornell University and USAID/Mali. The objective of the previous survey was to understand and develop food security indicators for IFAD by implementing a four round household survey in 10 villages in the district of Soboundou in the Niafunke *cercle*. Christiaensen (1998) provides a full description of the sample design and selection of households from the 1997-98 data. By resurveying these 245 households found in 2006 from the 1997-98 survey, a better understanding of regional change and poverty dynamics is possible. Information regarding sample attrition and the feasibility study undertaken to conduct this resurvey project is found in Dillon (2005)[4].

The data set is composed of a village questionnaire and a household questionnaire. The village questionnaire was administered to village leaders in each village or town concerned by the study. The household questionnaire is differentiated by men's, women's and children's sections. Respondents for each questionnaire were addressed to either the head of household for the men's survey, the head of household's wife for

[3] See Appendix 2 for a list of communes included in the study and a decomposition of the sample.
[4] Because of the multiple objectives in the survey design and sample attrition from the 1997-98 households, sample weights should be used when conducting data analysis.

the women's survey and each child for the children's survey. The questionnaire organization is provided in Appendix 1.

To ensure the representativeness of the sample, sample weights are included in the data set to account for the different selection probabilities between urban and rural stratas. Following common practice, urban residents have a higher selection probability than rural residents[5], so to equalize their respective weights when conducting analysis, sample weights should be used. Additionally, incorporating resurveyed households in 2006 from the 1997-98 survey posed a technical challenge. It was necessary to account for population changes between the two surveys and the selection probabilities for the 2006 sample, so that the appropriate weights could be assigned to the resurvey households. These weights are reported in the data set to facilitate data analysis. A description of the sample decomposition is provided in Appendix 2.

IV: Survey Implementation

The survey was conducted from February 2006 to October 2006 across northern Mali. Coordination of all data collection activities were assured by the Coordinator, a Research Assistant and a Field Supervisor/Trainer. 28 survey enumerators administered the survey throughout the different *cercles* by working in two person teams. These survey enumerators participated in a training and field test before

[5] In the urban stratas, 33% of quartiers were selected in the first stage selection with 8% of the population in the quartiers selected. In the rural stratas, 15% of the villages or fractions were selected in the first stage with 8% of the population of the villages or fractions selected. Two exceptions to this rule were the urban strata of Tombouctou which used a second stage selection probability of 4% due to the high concentration of its urban population and the rural strata of Niafunke which used a 15 % second stage selection probability to assure an adequate sample size with which to conduct program evaluation in the primary intervention zone of the funding institutions.

beginning their work. This enabled the screening of enumerators and the selection of the best possible candidates as well as providing an opportunity to field test the questionnaire before its implementation. Survey questionnaires consisted of a village level questionnaire, a men's questionnaire, a women's questionnaire and a children's questionnaire administered independently.

Survey teams first visited the selected villages to explain the survey's objectives and obtain oral consent from village leaders. Then the village population would be fully enumerated and the village questionnaire administered. The population lists were checked against official population statistics and for other anomalies before a random sample was selected from the list. Teams would then re-visit the village to conduct the household level component of the survey. Every effort was made to ensure that population lists were accurate, but the temporary displacement or refusal of a household to participate in the survey were occasionally encountered by the study. Replacement households were interviewed when it was determined that it was not feasible to interview the originally selected household. Households that were unable to be interviewed were replaced by their nearest neighbor as signified by the next household on the interviewer's list. Of the 2,658 households interviewed in the survey, 20 were replacement households. This constitutes a refusal or absentee rate of less than 1 %. This low refusal or absentee rate is due to the detailed enumeration of the population undertaken within close proximity to the time when selection and household interviewing was undertaken.

After teams finished the household component of the questionnaire, the household surveys were checked for consistency, quality and household omissions by the survey coordination. Errors in the questionnaires or inconsistent responses to questions were returned to enumerators for re-survey after review by a Coordinator or Field Supervisor. Data entry for completed questionnaires was then conducted by a team of six data entry personnel who worked throughout the year. Entered data was routinely checked for errors of internal consistency and validity by a Coordinator or Field Supervisor.

V: Data Collected

The four questionnaires administered in the field collected information from men, women, and children at the household level and from village leaders at the community level. One of the key issues that was extensively discussed during enumerator training was the definition of a household. Following FAO and World Bank definitions, we assumed the following working definition of a household:

A household is composed of members of a family who live together under the same roof, eat together in common, conduct common economic activities together, and mix their incomes for the mutual benefit of the other members of the household.

This definition of the household, as opposed to the family, has clear analogues in the Sonrai language as *cousou* and *hyinka*. Based on this definition, a wide range of variables were collected to analyze the household's agricultural production, income generating activities, herding, assets, education, health, and demographic composition. Questions concerning the household's composition, education, primary activities, migratory status of household members and history of positive and negative economic shocks were addressed to the head of household, usually a man. Questions concerning the household's food consumption, health and dietary diversity were addressed to women. Sections concerning possessions, non-food expenditures, agricultural production, herding activities, credit, and time allocation were addressed to both men and women. The children's questionnaire solicited the child's (aged 10-17) perspective on their work, schooling and leisure activities. Additionally, children 0-5 years old were weighed and measured to facilitate the analysis of child health. The essential modules and the methodology of conducting men's and women's questionnaires were retained from the 1997-98 survey, so that analysis between the two data sets would not be biased by questionnaire design. A full outline of the questionnaires is contained in Appendix 1 and a variable appendix with definitions for all variables used in the dissertation is contained in Appendix 3.

Household Statistics

2,658 households with 12,608 members participated in the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006*. Table 2.1 provides a summary of the decomposition of the sample from the 151 villages. 31% of the households in the sample come from urban areas while 69% of the households are from rural areas. Men composed 50.55% of those surveyed, while women made up the other 49.45%. Statistics regarding household size and the age distribution of the population are presented in Table 2.2. The mean number of people in the households surveyed was 6.24 persons. There is a difference of almost .5 persons between urban and rural households. The composition of the population is represented in the age pyramid reported in Figure 2.2 which illustrates that the population is heavily weighted towards the young. This is consistent with high fertility and mortality rates that explain high percentages of young people in the population, but lower numbers of people in older generations.

Table 2.1: Sample Decomposition

Urban Sample	664
Rural Sample	1,749
2nd Round 1997 HH Follow up	245
Total Cross Section	2,413
Total Sample Households	2,658

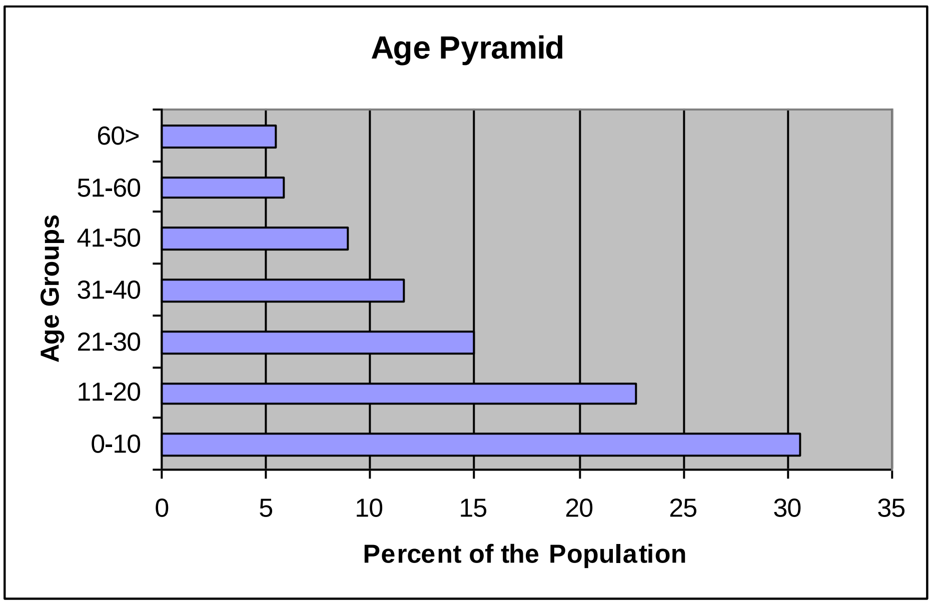

Figure 2.2: Age Pyramid

The migration of household members is a common strategy employed by households to spatially diversify risk and build networks to assure adequate resources for the household. Mean numbers of migrants associated with the household are reported in Table 2.2 along with migrant remittances decomposed for the full sample, the rural sector and the urban sectors. Rural households send one extra member on average to work than urban households. Migrants remitted an average of 28,480 FCFA in the three months prior to the survey interview. However, the amount of remittances to rural households is almost four times that for urban households.

Table 2.2 displays the mean value of the household's durable assets in FCFA. The household's durable assets were solicited from both men and women. These assets include agricultural materials (hoes, donkey carts, etc.), household furniture (tables, chairs, televisions, etc.) and means of transport (canoes, bicycles, motorcycles, etc.). Men and women were asked to value their assets at their current resale value if sold at the time of the interview. Mean values of durable assets between men and women differ by almost 85,000 FCFA. These inequalities are less persistent in urban areas than they are in rural areas.

Table 2.2: Sample Descriptive Statistics Disaggregated by Urban/Rural Strata

Variable (Mean)	Full Sample	Urban	Rural
Household Size	6.24	6.44	5.94
Number of Migrants	0.79	1.25	0.14
Migrant Remittances (FCFA)	28480	40042	11926
Durable Assets (Men)	282,710	425,728	202,600
Durable Assets (Women)	198,445	358,148	128,735
Household Weekly Food Expenditure	18,671	21,686	16,514
Non-Food Expenditures (Men)	230,981	450,307	112,668
Non-Food Expenditures (Women)	93,078	85,701	97,891
Household Area Cultivated (ha)	1.55	2.76	0.98
Agricultural Production (kg) per Hectare	2,071	2,116	2,049
Agricultural Capital (Men)	59,347	56,122	61,154
Agricultural Capital (Women)	4,403	8,417	2,651
Herd Size (Men)	20	4	31
Herd Size (Women)	33	24	40
Herd Value (Men)	554,366	121,399	865,787
Herd Value (Women)	179,739	74,668	249,098
Non Agricultural Revenue (Men)	107,143	189,298	49,631
Non Agricultural Revenue (Women)	31,372	47,386	20,391
Total Household Consumption	1,960,875	2,513,938	1,598,450
Consumption per Capita	340,318	443,141	272,937

Households' expenditures on food and non-food items are also described in Table 2.2. Women were asked to recount the household's food consumption expenditures over the previous seven days. Mean weekly food expenditures were 18,671 FCFA with more than a 5,000 FCFA difference between urban and rural households. These figures roughly correspond to a daily expenditure of a little less than 3,000 FCFA per day. Non-food expenditure is reported from men's and women's interviews over the previous three month recall period. Mean non-food expenditures for men are 230,981 FCFA while women spent 93,078 FCFA. There are again substantial differences between the urban and rural sectors in total non-food expenditures which are almost 40 % higher in urban than rural areas. Women assume much more responsibility in providing for family expenditures in rural areas than urban areas where the mean non-food expenditure for women in rural areas is actually higher than for women in urban areas. This may be because men account for approximately four times as many expenses in urban areas relative to rural areas, so that the distribution of expenses within the family changes according to the area. The next section will describe how households finance these food and non-food expenditures through livelihood strategies such as agriculture, herding and non agricultural work.

Production and Livelihood Statistics

Agriculture, herding, and non-agricultural commercial activities (artisanal crafts, small business, manual labor, skilled trades, etc.) are three dominant production and livelihood systems in northern Mali. Households often engage at various points in the year in all three. This allows households to diversify against risk in any one sector as well as earn income throughout the year.

Agricultural production is a dominant primary activity for both urban and rural residents. The primary crops produced across northern Mali for commercial and own-consumption are rice, sorghum and millet. Corn and wheat are of importance in certain *cercles* as are beans, onions and tomatoes. Various fruits and vegetables such as watermelons, okra, potatoes, and squash are also produced in gardens or on the periphery of irrigated fields.

Table 2.2 presents agricultural characteristics aggregated across the household's plots. The mean area cultivated by the household differs between the rural and urban sector with rural farmers cultivating approximately 150% more land than urban farmers. However, the productivity across rural and urban households is essentially equal with mean production (kg) per hectare equal to approximately two tons in both rural and urban sectors.

Access to agricultural capital is a critical input into the production of the household's food needs. Men and women have differing access to agricultural capital. In general, this stark difference may be because women do not have access to their own plots, even though they contribute significant amounts of labor to their household's plots. Table 2.2 shows that rural men have higher actual amounts of agricultural capital than urban men. More hectares cultivated may be an important factor in explaining this difference. However, urban women have larger values of agricultural capital than rural women. This difference may be explained by the fact that community gardening projects targeted at women are primarily placed in urban areas. Table 2.2 also presents mean productivity (kg per hectare) disaggregated by *cercle*. *Cercles* located along the river in the inner Niger delta (Niafunke and Dire) exhibit higher productivity yields than the other *cercles*. This may be because of inherent differences in soil quality between the *cercles*. Rharous and Bourem show the lowest productivity (approximately 1.3 tons per hectare) and in the most arid of the survey zone.

In addition to the importance of agricultural production as a livelihood system, pastoralism is a dominant primary activity for a smaller fraction of households in northern Mali. As a primary livelihood system, pastorialists seek to live off their animal stocks to increase wealth and generate revenue. As a secondary activity for most households in northern Mali, owning animals serves as an important store of wealth in the absence of a well developed financial system. However, these households shouldn't be necessarily considered trans-humant pastoralists. In our data women actually own more animals than men, but the value of these animals is considerably less than that of men's. This is primarily because women with fewer means own more chickens and goats, while men own cattle, sheep and goats. These trends are illustrated in Table 2.2.

In addition to agriculture, households are engaged in various income generating activities outside of agriculture. The net revenues of these activities were calculated from the survey data on gross revenues and expenses of the activity conducted in the previous month before the interview. Men gain consistently higher amounts of revenue across rural and urban sectors than women, but the differences in total net revenue gained between the sector is large. Men earn a mean net non-agricultural revenue of 107,143 FCFA while women earn only 31,372 FCFA (Table 2.2).

Table 2.3: Agricultural Production and Consumption by *Cercle*

	Niafunke	Goundam	Dire	Tombouctou	Rharous	Bourem
Agricultural Production (kg per hectare)	2,504	1,907	2,538	1,999	1,374	1,360
Consumption Aggregate (FCFA)	1,619,353	1,982,213	1,829,792	2,527,745	1,280,234	1,467,539

Poverty Analysis

Table 2.4 displays mean total consumption and consumption per capita for the full sample, the rural sector and urban sector in northern Mali. Consumption aggregates were calculated to reflect the use value during the year of the household's possessions, its non-food expenditures and its food expenditures. Mean total consumption per household is 1,960,875 FCFA with a difference of almost 1,000,000 FCFA between urban and rural households. Mean consumption per capita statistics display similar differences between rural and urban sectors with a difference of almost 285,000 FCFA per person per household.

Differences in total consumption are distinct not only across rural and urban sectors, but also across the different *cercles* of the study. Tombouctou has the highest total household consumption while Rharous has the lowest total household consumption. Although the two *cercles* border each other, these differences can be explained by the regional importance of the city of Tombouctou which serves as the region's commercial center and the isolation of Rharous as a *cercle* in which there is a significant lack of infrastructure and arable land.

Headcount, poverty gap and severity measures are reported for the full sample, urban and rural sectors and across the *cercles*. The poverty line is based on a common international standard of 1 Euro per person per day to delineate extreme poverty. This poverty line represents a yearly per capita income of 365 Euros or 239,217 FCFA. The poverty statistics for this poverty line are reported in Table 2.4.

The *cercles* of Rharous, Bourem and Niafunke are the poorest *cercles* considered in this sample. The urban poverty rate is approximately 18% of the population while rural poverty rate is almost 53%. The PSRP 2002 indicates that nationally the severe poverty rate is 21% which suggests that even in urban areas of northern Mali severe poverty is close to previous national averages, while rural poverty in northern Mali is more than twice the national average. In addition, significant differences in the dispersion of poverty as measured by the poverty gap and severity measures exist between the urban and rural regions.

Table 2.4: Poverty line--1 (2006) Euro per day per capita (239,217 FCFA)

	Headcount	Gap	Severity
Full Sample	0.388	0.120	0.053
Urban	0.181	0.038	0.012
Rural	0.529	0.176	0.082

VI: Conclusions

The objective of this chapter was to provide a description of the research methodology, sample design and a brief regional overview of the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006*. These summary statistics provide a general overview of differences between the *cercles* and the urban and rural sectors in northern Mali. The following three chapters explore the implications of child labor and access to irrigation in these data.

CHAPTER 3: CHILD LABOR AND SCHOOLING RESPONSES TO PRODUCTION AND HEALTH SHOCKS IN NORTHERN MALI

I. Introduction

Child labor is an economic imperative for many households, especially poor households in developing countries. The 2004 International Labour Organization estimate of working children aged 5-14 suggests that more than 190 million children work worldwide, of whom more than 49 million (26.4 percent of the region's child population) reside in Sub-Saharan Africa (Hagemann et al. 2006). Children contribute to household labor supply when reserves of labor are essential at critical periods of the production process, supervision of labor is costly, and household production by children frees other household members to pursue remunerative market activities. While some children do contribute income directly to households through formal wage labor,[6] most often children perform a combination of market activities and/or domestic activities, especially in Africa. These market activities include unpaid agricultural production on the family farm and formal or informal family businesses. Domestic activities include participation in the provision of household public goods such as food preparation, household cleaning, and provision of childcare for other siblings. Without children's work, poor households lose one of the few mechanisms they have to increase incomes or smooth consumption in the face of economic shocks. This chapter investigates children's time allocation to schooling, home production, and market production. It uses a unique data set collected from northern Mali to examine the marginal effects of production and health shocks on child time allocation. In

[6] A child agricultural wage rate was reported in only 7 percent of the villages we surveyed, indicating the lack of a child agricultural labor market. Manufacturing is not a predominant economic activity in northern Mali, so children's manufacturing wages were not collected in the village questionnaires.

addition, the chapter estimates the effect of assets on mitigating children's withdrawal from school and increased participation in work activities.

While the literature on children's schooling is extensive[7] and the fertility literature explicitly models the quantity/quality tradeoffs among additional children,[8] the child labor literature has focused on the causes of children's work (Basu and Van 1998; Basu 1999; Baland and Robinson 2000; Bhalotra and Heady 2003) and the substitution effects caused by household composition and birth order (Edmonds 2006b and Emerson and Souza 2007). Increasing attention has also been paid to the income effect of production shocks and the ex-post changes in the distribution of children's work and schooling caused by these shocks (Jacoby and Skoufias 1997; Jensen 2000; Beegle et al. 2006, de Janvry et al. 2006, Kruger 2007). As Edmonds et al. (2007) note, our understanding of the mechanisms that determine child labor and schooling substitution effects are a critical lacuna in the literature. This chapter contributes evidence regarding these substitution effects by using data that disaggregates children's work to better reflect the multiplicity of activities that children carry out in the developing world.

The chapter also contributes to the literature by developing a model of children's participation in market production, home production, and schooling. The model, developed in the chapter's second section, builds on Beckerian models of human capital investment in children within unitary household models (Becker 1965; Becker and Lewis 1973; and Becker and Tomes 1976), agricultural household models developed by Rosenzweig (1977a, 1977b, 1980), Singh et al. (1986), and de Janvry et

[7] See, for example, Strauss and Thomas (1995) and Glewwe (2002), for a review.
[8] See for example Becker and Lewis (1973).

al. (1991), and more recent models of child labor by Basu and Van (1998), Basu (1999), Baland and Robinson (2000), Cigno and Rosati (2005), and Edmonds (2007).

The third section of this chapter develops the econometric strategy for estimating the marginal effects of household and community characteristics and idiosyncratic shocks on schooling, home production, and market-oriented production. Three econometric specifications (a probit model, a probit model with shocks and shock asset interactions, and a multivariate probit model) are investigated with different assumptions about the structure of potential unobserved heterogeneity. These error term assumptions include household-level random effects, village-level random and fixed effects, and cross-equation correlation to check for consistency across parameter estimates. Outcome variables include children's participation in multiple types of activities and the child's role in joint production. These variables allow the examination of substitution effects within the household including the gender-specificity of tasks or the multiplicity of activities that children undertake. This analysis is infeasible when children's activities are aggregated into "work," rather than reported as specific activities in which a child engages. The econometric strategy uses production shocks from harvest-period pest infestations that reduce household income and illnesses within the family that reduce total household labor availability in order to identify substitution patterns of child labor and schooling.

The fourth and fifth sections of this chapter describe the survey and the data collected in northern Mali. The sixth section presents the empirical results and investigates the role assets play in insuring against shocks and as buffer stocks. Different measures of household assets are constructed to test whether assets indeed serve as buffers against increased child labor in response to shocks. Results from investigating asset-shock interactions suggest that different asset types provoke different substitution effects within the household. To ensure that these results are robust to concerns about unobserved heterogeneity, model specification and endogeneity, robustness checks are conducted that include disaggregating the sample by gender and age, examining the effects of omitting household composition variables, and estimating the probability that a household reports a shock. The last section offers conclusions.

II. Model

The purpose of this model is to examine the mechanisms by which children's time is allocated to different activities (education, home production, or market production) within an agricultural household model. The household decision problem is divided into three periods. In the first period, the household decides how many children to have given their existing birth-control possibilities, preferences, social norms, and expectations about the future of raising children. In the second period, the household incurs a fixed cost for each child born as well as the cost of providing food and consumption goods to the child in this period.

The second period requires households to invest in their children, which will determine the child's third period income. Investment in children comes from food and consumption goods provided to children, but also from the amount of schooling that children acquire. Parents allocate the time of their children between school, home production, and market production, deciding simultaneously their participation in these activities and the hours to be worked. The first and second periods can be thought of, in the Beckerian sense, as parental investment in both the quantity and quality of children. The third period ends as parents become old, consuming the return on their assets, and as children earn their own income.

For ease of exposition, consider the last two periods of the allocation process and assume that the household maximizes an additive utility function over these two periods, considering its own consumption in period 2 and a discounted valuation of children's consumption in period 3.

Building on the Cigno and Rosati (2005) model of child labor in a unitary household, let a_2 and a_3 be adult consumption in periods 2 and 3. Children's period 2 consumption and period 3 income are represented by c_2 and y_3. Parents maximize a separable utility function with arguments that include their own periods 2 and 3 consumption as well as a discounted function of their *n* children's period 2 consumption and period 3 income when they become adults and form their own households.

Household Utility Function: $U = u(a_2, a_3) + \beta n U^*(c_2, y_3)$ (3.1)

The household faces a budget constraint in each period. In the second period, the household must divide its revenue from market production and home production between adult consumption and assets or savings, denoted *k*. For each of the *n* children born in period 1, a fixed cost is also incurred, *b*, which includes all the costs of childcare in period 1. Two other costs are borne by the household in period 2, the child's period 2 consumption, c_2, and the cost of schooling for each child who is sent to school, *s*. If *s* is set to zero, then the child does not go to school. In period 3, adults no longer work and children form their own households. The budget constraint for the household in period 3 is simply the return on the household's assets invested from period 2.[9]

Budget Constraint Period 2: $Y_2 + H_2 + w_A{}^W T_A{}^W = a_2 + (b + c_1 + s)n + k$ (3.2)

Budget Constraint Period 3: $a_3 = rk$ (3.3)

Both adults and children have time constraints. Adults divide their time among self-employed market production, $T_A{}^F$, home production, $T_A{}^H$, the wage labor market, $T_A{}^W$, and leisure activities, $T_A{}^L$. Children divide their time among schooling, $T_C{}^S$, market production, $T_C{}^H$, home production, $T_C{}^H$, and leisure, $T_C{}^L$. Parents choose simultaneously whether children work in a particular activity and the hours worked. If a child's time is not allocated to a particular activity, the child's time is set to zero. Because there is a low incidence of child wage labor in northern Mali, only the adult's return in the wage labor market is modeled.

The household generates profits from agricultural production or a home business via the market profit function in Equation 3.4. The revenues from the business are generated by scaling output from the production function, *f*, that converts adult and child labor given the quasi-fixed inputs capital, *K*, and land, *L*, by a vector of output prices, *p*. Adult and child labor inputs are valued at wage rates that represent the opportunity cost of the adult or child's time. Domestic profits are valued according to

[9] Implicitly, the model makes two assumptions in Equations 3.2 and 3.3. The first is that period 1 production, consumption, and labor supply decisions have no impact on period 2 decisions. Second, the absence of credit markets and borrowing are constraints for households. Credit market transactions are small with short term loans that do not exceed one of the periods purposed by the model. Credit contracts of long duration or debt bondage are not considered in this model.

a home production function minus the labor inputs that generate the final goods. Both production functions are quasi-concave functions.

Market Profits in Period 2: $Y_2 = p\delta q(T_C^F, T_A^F \mid K, L) - w_A^F T_A^F - w_C^F T_C^F$ (3.4)

Domestic Profits in Period 2: $H_2 = h(T_A^H, T_C^H) - w_A^H T_A^H - w_C^H T_C^H$ (3.5)

δ is a random production shock included in Equation 3.4 with $E(\delta)=1$ and an i.i.d. distribution that represents unexpected positive or negative production shocks. These could include rainfall variation, crop losses due to insect or animal infestations, or household illness that affects market production.

The child's period 3 income is the return that the child (now an adult) receives on her labor given her cognitive development, *E*, and period 1 and 2 consumptions. The child's period 3 income is a function of her cognitive skills, *E,* which are developed in period 2, and of period 2 consumption, c_2, which determines physical development and work capacity. Childhood nutrition is a critical component of future adult health, which contributes to the adult's work capacity in period 3.

Income Generation in Period 3: $Y_3 = w_3(E, c_2)$ (3.6)

Cognitive development is represented by a production function, *E* (Equation 3.7) with inputs including the child's time in school, $T_C{}^S$, schooling inputs such as books, *s*, and the school's quality, *Q*. Following Glewwe (2002), a parameter of the learning efficiency of the child that is exogenously given is specified as θ. As θ increases, the cognitive development of the child increases. Included in θ are unobservable characteristics that increase a child's cognitive development, such as innate ability, the child's motivation, and the parent's motivation to help the child learn. These unobservable characteristics are grouped in the vector θ. The interaction between unobservable individual and household characteristics with school quality and time in school produces cognitive skills.

Cognitive Skills: $E = \theta f(Q, s) g(T_C^S)$ (3.7)

The full model is outlined in Appendix 1, but testable implications are developed from the solution to the household's problem summarizing the conditions under which children's time is allocated to schooling, home production, and market production. The comparative statistics of household shocks on child labor and schooling are also derived, and can be tested with the data.

School

Equation 3.8 defines the schooling participation equation to be estimated. ${S^{C*}}_{i,h}$ is a discrete choice that depends on the following factors. First, if the shadow value of the child's time is relatively high, then the demand on the child's time in either the home or market production of the household in period 2 will outweigh any future benefit in period 3 that schooling may provide. Factors that increase child schooling include school quality, which increases the future benefits of cognitive skills. A child's unobservable characteristics and her parent's motivation to help her succeed in school, represented by θ, will also increase the benefits of schooling and make the development of cognitive skills more desirable.

Schooling Condition: $S^{C*}{}_{i,h} \equiv \beta n \frac{\partial U^*}{\partial y_3} \theta f(Q,s) g'(T_C{}^S) > \lambda_1$ (3.8)

Home Production

The child's participation in home production can be explored by transforming Equation A.8[10] such that:

$$h'(T_A{}^H, T_C{}^H) = \frac{\lambda_1}{\partial u / \partial a_2} + w_C{}^H \quad . \qquad (3.9)$$

Using the Implicit Function Theorem, Equations A.8 could be solved to derive the optimal hours worked by the household's child for the general case. Alternatively, if a Cobb Douglas production function is assumed for *h*, a closed form solution can be derived. By using this functional form, child and adult labor become either complements or substitutes. Much of the child labor literature suggests that child and adult labor are substitutes. However, complementary adult and child labor seems to be the more intuitively plausible because it is relatively rare to see children working without adult supervision. This proposition is testable using analysis of the asset-shock substitution effects. Using the functional form assumption for the household production function, the household child labor demand becomes:

[10] Equations referenced are found in Chapter 3, under VIII: Model.

$$T_C{}^H = \left[\frac{w_C{}^H + \dfrac{\lambda_1}{\partial u / \partial a_2}}{(1-\alpha)(T_A{}^H)^\alpha}\right]^\alpha \quad . \tag{3.10}$$

If $T_C{}^H = 0$, then Equation 3.11 characterizes the equilibrium condition. When the shadow value of the child's time and the increase in the adult's marginal utility from the return on the child's time in home production are greater than the marginal utility from the change in productivity of the home production function due to the child's labor, it is inefficient to allocate the child's time to home production. The child's participation in home production is characterized as a discrete choice, $L^{C*}{}_{i,h}$.

Home Production Condition: $L^{C*}{}_{i,h} \equiv \frac{\partial u}{\partial a_2}\left(h'(T_A{}^H, T_C{}^H\right) > \lambda_1 + \frac{\partial u}{\partial a_2} w_C{}^H$ (3.11)

Market/Farm Production

The analysis of the allocation of children to the market production activities of the household is similar to the decision rules for the home production activities. However, the household's decisions are driven by the marginal returns of allocating additional hours of child labor to market/farm production and the return to the child of each additional unit supplied. Manipulating Equation A.9 yields:

$$p\delta q'(T_A{}^F, T_C{}^F) = \frac{\lambda_1}{\partial u / \partial a_1} + w_C{}^F \quad . \tag{3.12}$$

A closed form solution, assuming the Cobb-Douglas production function yields:

$$T_C{}^F = [\frac{w_C{}^F + \frac{\lambda_1}{\partial u / \partial a_1}}{p\delta(1-\alpha)(T_A{}^F)^\alpha}]^\alpha \quad . \tag{3.13}$$

If $T_C{}^F = 0$, then from the first order conditions Equation 3.14 must hold which characterizes the discrete choice of child labor in market production.

Market Production Condition: $$L^{C*}{}_{i,h} \equiv \frac{\partial u}{\partial a_2}\left(q'(T_A{}^F, T_C{}^F\right) > \lambda_1 + \frac{\partial u}{\partial a_2} w_C{}^F \tag{3.14}$$

Equation 3.14 states that when the marginal utility value of adding an additional unit of child labor to market production exceeds the shadow value of the child's time and the shadow wage, then a child will be allocated to market production. Together with Equation 11, these equations suggest there are thresholds over which children's time is allocated to certain types of market and domestic production. The importance of covariates suggested by these participation conditions on observed child labor decisions are estimated in the sample of children from northern Mali in section 6.

Response to Shocks in Market Production

The changes in child labor in response to market production shocks are characterized by taking the derivative of the child labor demand equation with respect to the production shock:

$$\frac{\partial T_C^F}{\partial \delta} = -\alpha\left[\frac{w_C^F + \frac{\lambda_1}{\partial u / \partial a_1}}{p\delta(1-\alpha)(T_A^F)^\alpha}\right]^{\alpha-1} \frac{w_C^F + \frac{\lambda_1}{\partial u / \partial a_1}}{p\delta^2(1-\alpha)(\gamma_A)^\alpha} < 0 \quad . \tag{3.15}$$

In response to positive production shocks, households decrease child labor supply to market activities. Negative production shocks induce larger allocations of children's time to income generating or subsistence activities. Child and adult productivity shocks have inverse effects on allocation of child time to work. This is because the marginal value of children's labor input increases when less labor is allocated to the production process. The responses of both production and health shocks can be tested empirically in these data.

III. Econometric Specification

Three different econometric specifications are used to investigate allocation of children's time in home production activities such as childcare provision,[11] market activities such as agricultural production and small family business activities, and school enrollment. Participation in any of these activities is indicated dichotomously by the latent variables $L^{C*}{}_{i,h}$ and $S^{C*}{}_{i,h}$, which were derived above. For simplicity, all child work and school participation decisions are specified as $L^{C*}{}_{i,h}$ below. The three econometric specifications represent three different sets of identification assumptions about the structure of the disturbance term and the inclusion of crop loss shocks and household health shocks.

[11] 87 percent of children in our survey reported doing domestic chores, so while this category of work performed by children is the highest category in terms of percentage of children participating, estimation of the determinants of this activity is not possible given the lack of variation in the dependent variable.

Specification 1: Selection into Activities: Probit with Random Effects

To estimate the probability of selection into child labor, a probit model is specified for each of the sectors independently for which a child works, given household and individual specific covariates ($X_{i,h}$), community covariates ($Z_{i,h}$), a household effect on each child (c_h), and a child/household unobservable ($\varepsilon_{i,h}$), which can be combined in a composite error term: $\nu_{i,h} = c_h + \varepsilon_{i,h}$. The following equation is specified such that:

$$L^{C*}{}_{i,h} = \beta X_{i,h} + \gamma Z_h + \nu_{i,h} \,. \tag{3.16}$$

where $L^{C}{}_{i,h} = 1$ if $L^{C*}{}_{i,h} > 0$ (3.17)

$= 0$ otherwise

and obtain the distribution of $L^{C}{}_{i,h}$ given $X_{i,h}$, $Z_{i,h}$, and c_h using the familiar result:

$$\begin{aligned} P(L^{C}{}_{i,h} = 1 \mid X_{i,h}, Z_h, c_h) &= P(L^{C*}{}_{i,h} > 0 \mid X_{i,h}, Z_h, c_h) \\ &= P(\varepsilon_{i,h} > -\beta X_{i,h} - \gamma Z_h \mid X_{i,h}, Z_h, c_h) \\ &= 1 - \Phi(-\beta X_{i,h} - \gamma Z_h) = \Phi(\beta X_{i,h} + \gamma Z_h) \end{aligned} \tag{3.18}$$

where $\Phi(.)$ is the standard normal cumulative distribution function. Following Butler and Moffitt (1982), the conditional likelihood function can be derived to estimate the joint distribution of $L^{C}{}_{i,h}$ conditional on $X_{i,h}$ and Z_h, which requires that the random effect is integrated out of the likelihood function.

The cognitive skills production function (Equation 9) implies that there is an unobservable term, θ, that is partially household-specific and influences children's learning efficiency, through parental involvement in the child's learning. Because this term is determined in part from parental involvement in the child's learning and the child's genetic and psychological disposition to learning, a random effect that potentially varies among children within the household seems to correspond closely to the proposed theoretical model. Besides the theoretical motivation for investigating household-level effects on children's work and schooling, there is empirical evidence that suggests parental preferences have large effects on children's schooling decisions. For example, 54 percent of children aged 11-17 in Senegal reported that they had not been to school because their parents refused to send them, while 19 percent had not attended school because their parents needed their help to meet subsistence requirements (Dumas and Lambert 2004). This suggests that household preferences may influence children's time allocation patterns. Household fixed effects are not a feasible econometric strategy to control for household unobservables because other fixed household characteristics such as household assets or parental education will not vary across children, but have a potentially influential role on children's schooling and work. Therefore, to control for both household unobservables and observable household characteristics that do not vary between children, a random effects specification is employed.

Econometrically, there are certain advantages to using a probit model with random effects to control for household unobservables. Maddala (1987) argues that an unobserved household heterogeneous effect, c_h, for which there is information and/or some a priori belief that it might not be fixed, ought to be treated econometrically as u_{ih}, in order to measure the household-specific effects about which the econometrician is also ignorant. Since fixed effects capture all time-invariant characteristics of the cross-sectional units, no estimate of the effect of parental education or household assets on child work and school participation would be possible.[12] In addition, the household fixed effects estimator suffers from the incidental parameters problem, which renders the maximum likelihood estimates inconsistent.

Random effects estimation is not without innocuous statistical assumptions that require consideration. Identification is conditioned on assumptions regarding the relationship between the random effect and the covariates and distributional assumptions. Precisely, these assumptions are:

1. *Strict Exogeneity*: $P(y_{ih}=1|x_i,c_i)=P(y_{ih}=1|x_{ih},c_i)=\Phi(\beta x_{ih}+c_i)$
2. $y_{i1},\ldots,y_{iH}$ are independent, conditional on (x_i,c_i)
3. $c_h|x_h \sim Normal(0,\sigma_c^2)$

Given a priori beliefs about the nature of the household's child work and schooling decisions and econometric arguments, three econometric specifications are proposed to measure the effects of children's home production, market production, and schooling given household, parental, child-specific and community covariates, using household random effects. As a robustness check, the results of the random effects and fixed effects estimation at the village level are also reported.

[12] Several examples of random effects estimation in the children's health and education literature include Pitt (1997), Glick and Sahn (1999, 2005), or Paxson and Schady (2005).

Specification 2: Investigating the Impact of Agricultural Shocks and Household Morbidity

Building on specification 1, household-reported sicknesses and production shocks that result in crop losses that are rated in severity by the farmer (large or small) are included in the second specification. The sickness shocks are disaggregated into men's illness, women's illness, and children's illness where sickness is defined as having at least one day in the previous month when the respondent was unable to work due to feeling ill. Including the shocks in the probit model specified as in Equation 16 yields:

$$L^{C*}_{i,h} = \beta X_{i,h} + \gamma Z_h + \phi Shock_{i,h} + c_h + \varepsilon_{i,h} \quad . \tag{3.19}$$

Exogeneity of Shocks

Self-reported health shocks may not be a reliable measure of health if reporting is correlated with wealth and education (Strauss and Thomas 1995). Production shocks also may be endogenous if households' ex-ante decisions mitigate the expected risk of seasonal variations. A simple test of the plausibility of the shock's exogeneity estimates the probability that a household reports a shock, controlling for observable household characteristics that may likely be correlated with the reporting itself. If these covariates are significant determinants of the probability of experiencing a shock, it would be difficult to argue that the shock is exogenous. The following specification is estimated:

$$P(shock_h = 1) = f(X_{ih}, Z_h) \ . \tag{3.20}$$

This exogeneity test examines correlations between household characteristics and self-reported morbidity or crop-loss shocks. Alternatively, using a small subset of panel data from the survey also produces evidence regarding the strict exogeneity assumption. The specification below controls for previous shocks to illustrate that the effects of self-reported morbidity and crop-loss shocks are transitory. If lagged shocks have persistent effects on the dependent variable, then the strict exogeneity assumption on which the random effects estimate depends would be questionable. Equation 21 includes controls for time-invariant household and community characteristics and includes household fixed effects.

$$L^{C*}{}_{i,h,2006} = \beta X_{i,h} + \gamma Z_h + \phi_{2006} Shock_{i,h,2006} + \phi_{1997} Shock_{i,h,1997} + \varepsilon_{i,h} \quad (3.21)$$

Smoothing Shocks: The Role of Assets

Several categories of assets, including the values of the household's durable goods, agricultural capital, and livestock, are of particular interest because of their varying liquidity. Faced with production and health shocks, households may choose to liquidate assets rather than change the allocation of children's time. These shocks are interacted with the asset types in the probit model such that Equation 19 becomes:

$$L^{C*}{}_{i,h} = \beta X_{i,h}\beta + \gamma Z_h \gamma + \phi Shock_{i,h} + \alpha(Shock_{i,h} \cdot Assets_{i,h}) + c_h + \varepsilon_{i,h}\,. \quad (3.22)$$

This specification can provide some evidence with respect to the role of assets in mitigating ex-post responses to shocks that include increasing child labor. However, a strictly causal interpretation is difficult due to the cross-sectional nature of the data. Observing household asset stocks before and after a shock would be ideal, but variation within the cross-section of asset stocks interacted with the shock, controlling for seasonality, can also give evidence about the role that asset stocks may have in mitigating child labor responses to shocks.

Specification Three: Multivariate Probit

The previous econometric specifications treated the dependent variables as independent decisions in an equation-by-equation specification. However, the theoretical modeling suggests that cross-equation correlation is likely. Parents potentially make decisions jointly across the multiple activities in which children could participate. These cross-equation correlations can be modeled by using a multivariate probit model such that:

$$
\begin{aligned}
S_{1\ i,h}^{C*} &= \beta X_{i,h} + \gamma Z_h + \phi Shock_{i,h} + \varepsilon_{1;i,h}\,, \\
L_{2\ i,h}^{C*} &= \beta X_{i,h} + \gamma Z_h + \phi Shock_{i,h} + \varepsilon_{2;i,h}\,, \\
L_{3\ i,h}^{C*} &= \beta X_{i,h} + \gamma Z_h + \phi Shock_{i,h} + \varepsilon_{3;i,h}\,, \\
L_{4\ i,h}^{C*} &= \beta X_{i,h} + \gamma Z_h + \phi Shock_{i,h} + \varepsilon_{4;i,h}\,,
\end{aligned}
\tag{3.23}
$$

where each subscripted equation, $L_{m\ i,h}^{C*}$, m=1,2,3,4, represents an activity for which a child may participate dichotomously. To facilitate the interpretation of the effects of shocks on schooling for children, $S_{1\ i,h}^{C*}$ is defined as the discrete choice of whether the child was withdrawn from school in the previous year. Conditional on the child having been enrolled in school the previous year, the interpretation of the shock variables are cleanly identified. The relevant question is whether production and health shocks are causing students to withdraw from school. School enrollment for children not enrolled in school during the last academic year will be unaffected by shocks in the same year.

Restrictions on the residuals, $\varepsilon_{m;i,h}$ require:

$$E(\varepsilon_{m;i,h} \mid X_{i,h}, Z_h) = 0,$$
$$Var[\varepsilon_{m,i,h} \mid X_{i,h}, Z_h] = 1,$$
$$Cov[\varepsilon_{m;i,h}, \varepsilon_{m+1;i,h} \mid X_{i,h}, Z_h] = \rho \text{ where } \rho_{jk} = \rho_{kj}. \quad (3.24)$$

Using the Geweke-Hajivassiliou-Keane (GHK) simulator, the system of equations in 3.24 can be estimated by evaluating the four-dimensional normal integrals in a likelihood function (Geweke et al. 1994).

IV. Data Description

The Survey Area: Northern Mali

The regions of Tombouctou, Gao, and Kidal lie in the arid and semi-arid regions of northern Mali. The most southwesterly communes of the region of Tombouctou are located in the inner Niger Delta, where the Niger River breaks into multiple streams to irrigate small ponds and lakes that supply water to otherwise parched soils that are increasingly sandy from the climactic forces of desertification. The defining geographic feature of this region is the juxtaposition between the vast and desolate Saharan desert and the third largest river in Africa, the Niger, which meanders northeasterly until it reaches its most northern point in the commune of Bourem before descending past the ancient city of Gao into the country of Niger. Besides providing the primary water source in an otherwise arid zone, the Niger River is a primary transportation route, enables fishing for food and the cultivation of floating rice, and provides grasses called *bourgou* (Echinochloa stignina) for the alimentation of livestock.

Rainfall in the three regions is scarce and intermittent during the rainy season which is generally considered to span July to September. The Saharan zone (desert or arid regions) receives less than 150 millimeters of rainfall per year. This varies starkly with the Sahelien zone (grassland or semi-arid regions), which receives 200-600 millimeters per year, and the south of Mali, which can receive between 600 and 1200 millimeters per year (Christiaensen 1998). Depending on the date of planting, the primary harvest begins in October and could last into December or early January. Grains, particularly rice, sorghum, and millet are the primary crops cultivated. December and January are the coldest periods, which lead to the hot and hunger seasons that span from February to June. During this period, a limited number of counter-seasonal crops are produced, but these are cultivated mostly from smaller garden plots than from the larger plots used for grain cultivation during the primary agricultural season. The school year usually begins in September and ends in June, leaving children available for planting, but potentially occupied with schooling during the harvest season. Rainfall scarcity is counterbalanced by irrigation from the Niger River and lake recession agriculture in the inner Niger delta. The source of the Niger River, Tembakounda, lies in the Djallon Mountains of Guinea, where rainfall is siphoned into the river, determining its volume for the most part.[13] But after the rainy

[13] Christiaensen (1998) provides a detailed description of river levels and rainfall data that illustrates this relationship. In particular, this is why rainfall data is unlikely to be correlated with production yields. According to the EPSANM 2006, 22 percent of farmers use irrigation drawn from the Niger River (Dillon 2006). The timing and levels of this flooding and water recession are the critical

season in the mountains ends, river levels diminish, exacerbating water scarcity in northern Mali. As a result, primary and secondary tributaries along the river's primary bed dry up completely.

Seventy-three percent of households in our survey participate in agriculture as a primary activity. Primary activities are predominantly determined by ethnicity, with the Sonray, Soninké, and Bambara being the primary cultivators; the Peuhl, Tamasheq, Berabich, and Maures the traditional pastoralists; and the Sorko, Korongoy, and the Bozo deriving their livelihood from fishing. However, there is idiosyncratic variation across communities, most notably among selected Tamasheqs, who, after the Touareg rebellion of 1990-96, increasingly have become more sedentary as part of governmental and nongovernmental interventions.

Poverty is a widespread phenomenon in Mali, but specifically in the rural regions of northern Mali. The region has known several significant economic shocks, including widespread drought and famine in 1914, 1973, and 1984, as well as the civil conflict noted above in the early 1990s. The Government of Mali's *Poverty Reduction Strategy Chapter 2002* reports a national poverty rate of 63.8 percent, with severe poverty in the country at the 21 percent level. Indicators from the *Rapport National 2003 sur le développement humain durable au Mali* (RNDH 2003) illustrate the entrenchment of rural poverty at the communal level in the north, as compared to other regions of Mali. Because northern Mali is geographically isolated and considered to have less potential than other regions of Mali, differences in public investment are

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covariates in these production systems. They determine water availability and thus agricultural income, not local rainfall.

stark.[14] According to the 2003 *Rapport National*, 33 percent of communes in Tombouctou, 30 percent in Kidal, and 35 percent in Gao had no access to primary schools in 1998. Other regions further south and west of these northern regions had far lower percentages of communes without access: Kayes (13 percent), Koulikoro (1 percent), Sikasso (6 percent), Segou (4 percent), and Mopti (7 percent).

Survey Design

The data for this chapter were collected as part of the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali (EPSANM) 2006*. This multi-topic household survey was implemented to study household behavior related to human capital formation and household production activities, including agriculture, herding, and nonfarm activities in northern Mali. A representative cross-section of 2,155 households in 151 villages was undertaken from February 2006 to October 2006 in seven *cercles* or states (Niafunke, Goundam, Dire, Tombouctou, Rharous, Bourem, and Kidal) in the regions of Tombouctou, Gao, and Kidal. Households were drawn randomly using a two-stage cluster sample. Detailed documentation of the survey design and methodology can be found in the previous chapter.

The data set is composed of a village questionnaire and a tripartite household questionnaire. The village questionnaire was administered to village leaders in each village or town covered by the study. The household questionnaire comprised modules for an adult male, adult female, and child. Survey modules concerning the

[14] The concept of *Le Mali inutile* became a popular characterization of northern Mali, which was considered useless due to low production possibilities as deemed by USAID and the World Bank, especially after the 1974 droughts. See Poulton and ag Youssouf (1998) for a detailed recent history of northern Mali.

household's composition, education, primary activities, migration, and history of positive and negative shocks were addressed to the household head, usually a man. Questions concerning the household's food consumption, health, and dietary diversity were addressed to women. Sections concerning possessions, nonfood expenditures, agricultural production, herding activities, credit, and time allocation were addressed to both men and women. The children's modules were addressed to children aged 10-17 years old with questions about their participation in multiple household and market production activities and schooling, the hours worked during the past week in these activities, and the time spent on a set of activities in order to determine the distribution of time amongst work, school, and leisure. A second section of questions collected more detailed schooling information for all children enrolled in school.

V. Descriptive Statistics

Children's participation rates in schooling, home production, and market-oriented production are summarized in Table 3.1[15]. Thirty-three percent of children in our survey are currently in school, the lowest percentage of any category of activity. Another indicator of children's schooling status is whether children were withdrawn from school in the last academic year. Of students who were enrolled, 18 percent were withdrawn. Most children (87 percent) do some household work, while 45 percent are responsible for watching other children within the family. Market-oriented productive activities also have high child participation rates, with farm work occupying 54 percent of children in the survey and work in the family business[16]

[15] The percentage of idle children in our survey is only 2 percent. That is, children who neither work nor go to school.

[16] In northern Mali, family businesses are primarily run by women who have small enterprises, usually manufacturing condiments for food, artisanal goods, or housewares such as mats or kitchen tools. Products are sold on weekly market days as a supplement to household income.

occupying almost 68 percent. Children's joint production activities are also summarized in Table 3.1. Twenty-five percent of children combine some market work with school. Twenty-eight percent combine domestic work with school, while only 20 percent of children perform some market work and domestic work.

Table 3.1: Participation by Activity, Children 10-17 years

Participation by Activity	Mean	Std. Err.
Child Care	0.449	0.016
Domestic Chores	0.870	0.010
Work in the Family Business	0.677	0.015
Farm Work	0.542	0.015
School	0.334	0.015
Child Care + Domestic Chores	0.880	0.010
Family Business + Farm Work	0.845	0.011
Joint Production		
Market Work + School	0.247	0.014
Domestic Work + School	0.278	0.014
Market Work + Homework	0.204	0.013
Changes in Child's School Enrollment		
Withdrawn from School in the Last Year (N=761)	0.179	0.019

Notes: For all variables, N=1859, except Withdrawn from School (N=761). Withdrawn from school last year is conditional on the child having been enrolled in the previous school year. Discrete variables, domestic work and market work, are aggregated from children's activities: Market Work = Family Business + Farm Work and Domestic Work= Child Care + Domestic Chores. All variables are population weighted means and the standard errors are corrected for clustering.

Northern Mali's child labor rates are higher than regional means. The ILO estimates that 26.4 percent of children in Sub-Saharan Africa performed some type of economic activity in 2004 (ILO 2006). Within West Africa, Dumas and Lambert (2004) report that of children aged 11-17 in Senegal, 67 percent attended school, 69 percent reported participating in domestic work, and 25 percent participated in non-domestic work.[17] Higher mean participation rates in work activities and lower schooling rates may reflect higher poverty levels and less public infrastructure in northern Mali relative to other African countries.

Tables 3.2.A and 3.2.B present disaggregated children's participation rates across activities by sex and urban/rural area. Girls bear most of the responsibility for domestic work as defined by both watching other children in the household and doing domestic chores. A higher percentage of urban girls than rural girls participate in domestic work, although the differences between participation rates is most striking for domestic childcare that girls provide to the family. Forty-nine percent of rural girls watch other children in the family, while 74 percent of urban girls do so. The distinction between urban and rural boys is also wide with 36 percent of rural boys and 61 percent or urban boys being responsible for watching other children. Ninety percent of urban boys also do some sort of domestic chores, whereas 79 percent of rural boys do so. Rates of participation in domestic chores for girls are high in both urban and rural areas, with rates of 97 percent and 95 percent, respectively. Studies from Ghana, such as Bhalotra and Heady (2003), report rural school participation rates for girls and boys at 68.9 percent and 76.5 percent; farm work at 34.4 percent and 40.5 percent; and joint participation in school and farm work at 29.9 percent and 24.6 percent, respectively[18].

[17] L'Enquete Education et Bien-Etre des Menages au Senegal 2003 investigates multiple types of children's domestic and market-oriented activities (Dumas and Lambert 2004), suggesting that these results are a good comparison for EPSNAM 2006.

[18] Bhalotra and Heady (2003) use the rural sample from the Ghana Living Standards Survey 1991/92 for children aged 7-14.

Table 3.2.A: Participation Rates of Boys and Girls (10-17 years) in Rural and Urban Areas

Activity		Rural	Urban	Girls	Boys
Child Care	Mean	0.4164	0.6698	0.5219	0.3871
	Std. Error	0.0483	0.0715	0.0526	0.0466
Domestic Work	Mean	0.8600	0.9352	0.9531	0.7997
	Std. Error	0.0242	0.0342	0.0122	0.0330
Work in the Family Business	Mean	0.6747	0.6813	0.7325	0.6278
	Std. Error	0.0440	0.0722	0.0367	0.0450
Farm Work	Mean	0.5687	0.3706	0.3565	0.7001
	Std. Error	0.0285	0.0827	0.0418	0.0316
School	Mean	0.3177	0.4619	0.3233	0.3465
	Std. Error	0.0405	0.0530	0.0410	0.0395
Joint Production					
Market Activities and School	Mean	0.2390	0.3029	0.2162	0.2729
	Std. Error	0.0343	0.0365	0.0381	0.0336
Domestic Activities and School	Mean	0.2564	0.4354	0.2936	0.2670
	Std. Error	0.0328	0.0519	0.0406	0.0301
Market and Domestic Activities	Mean	0.2009	0.2281	0.2216	0.1899
	Std. Error	0.0358	0.0723	0.0401	0.0315

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1859.

Table 3.2.B: Participation Rates of Boys and Girls (10-17 years) in Rural and Urban Areas

Activity		Rural Girl	Urban Girl	Rural Boy	Urban Boy
Child Care	Mean	0.4893	0.7398	0.3559	0.6082
	Std. Error	0.0560	0.0603	0.0477	0.0845
Domestic Work	Mean	0.9501	0.9730	0.7853	0.9019
	Std. Error	0.0136	0.0130	0.0357	0.0568
Work in the Family Business	Mean	0.7366	0.7051	0.6232	0.6603
	Std. Error	0.0413	0.0576	0.0498	0.0855
Farm Work	Mean	0.3762	0.2254	0.7285	0.4984
	Std. Error	0.0434	0.0927	0.0311	0.0778
School	Mean	0.3117	0.4009	0.3227	0.5157
	Std. Error	0.0464	0.0700	0.0445	0.0446
Joint Production					
Market Activities and School	Mean	0.2135	0.2345	0.2602	0.3631
	Std. Error	0.0435	0.0412	0.0380	0.0386
Domestic Activities and School	Mean	0.2802	0.3829	0.2367	0.4815
	Std. Error	0.0458	0.0659	0.0313	0.0493
Market and Domestic Activities	Mean	0.2250	0.1982	0.1808	0.2544
	Std. Error	0.0438	0.0915	0.0344	0.0678

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1859.

Work in the family business does not differ with respect to urban and rural areas. However, participation in the family business differs between girls and boys by a rate of almost 11 percent. Another market-oriented activity, farm work, shows distinct rural/urban and boy/girl differences. Rural boys and urban boys farm with rates of participation of 73 percent and 50 percent, respectively, whereas only 38 percent of rural girls and 23 percent of urban girls work on the farm. With regard to children's participation in schooling, rates of schooling differ across rural and urban areas, but they are similar between girls and boys. Forty-six percent of urban children go to school while only 32 percent of rural children are currently being schooled. Girl and boy school participation rates differ by only 2 percent, with boys favored slightly.

Summary statistics of the child, parental, and household characteristics are summarized in Tables 3.3.A and 3.3.B. Boys comprise 54.5 percent of the children in the sample.[19] The distribution of ages, restricted to children between 10 and 17 years old, is presented as indicator variables of each age reported from the household roster. Because official administrative record-keeping has only recently become common at the commune level in Mali and a high percentage of natural births outside of hospitals are common, correct reporting of a child's age can be difficult. There seems to be some grouping of children's ages around even numbers (10, 12, 14, and 16 year olds), with odd ages reporting lower numbers. There is no particular natural phenomenon that could explain this pattern, so the interpretation of age-specific results should be conducted with caution in light of potential measurement error in the age variable. In addition to age, sex, and ethnicity, the child's relationship to the head of household is reported. The household head is plausibly the primary decision maker whose influence on the child's work and schooling may in part be dictated by social relationships. Eighty percent of children are the biological offspring of the head of household.

[19] This deviation from proximate parity in the sex ratio suggests that girls and boys may have characteristics which systematically differ, causing higher migration out of northern Mali or higher mortality rates. The assumption of pooling both genders will be relaxed in the forthcoming econometric investigation to test this proposition.

Table 3.3.A: Descriptive Statistics: Household and Child Characteristics

	Mean	Std. Dev.
Child Characteristics		
Sex (Boy=1)	0.545	0.498
Ethnicity		
Sonrai	0.665	0.472
Tamasheq	0.134	0.341
Peuhl	0.111	0.313
Bambara	0.040	0.196
Other Ethnicity	0.050	0.217
Age Dummies		
Age 10	0.201	0.401
Age 11	0.075	0.264
Age 12	0.138	0.345
Age 13	0.085	0.279
Age 14	0.135	0.342
Age 15	0.129	0.335
Age 16	0.145	0.353
Age 17	0.091	0.287
Adult Characteristics		
Mother's Education (1 if any education)	0.055	0.227
Father's Education (1 if any education)	0.106	0.308
Age of Household Head	41.2	21.6
Age of Household Head's spouse	33.7	14.7

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1859.

Table 3.3.B: Descriptive Statistics: Household and Child Characteristics

	Mean	Std. Dev.
Household Composition		
Own Child	0.803	0.398
Number of Girls in HH	1.407	1.215
Number of Boys in HH	1.722	1.361
Number of Adult Women in HH	1.697	1.277
Number of Adult Men in HH	1.638	1.148

Table 3.3.B (Continued)

	Mean	Std. Dev.
Household Assets and Unearned Income		
Herd Size	19.18	19.54
Herd Value (FCFA)	531946	57044
Agricultural Capital (FCFA)	47051	12744
Durables (FCFA)	302671	69356
Migrant Remittances (FCFA)	40508	114356
Shocks		
Production Shock		
No Crop Loss	0.533	0.042
Small Crop Loss	0.217	0.034
Large Crop Loss	0.250	0.036
Labor Availability Shock		
Adult Male Sick	0.131	0.019
Adult Female Sick	0.212	0.045
Child Sick	0.144	0.037

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1859.

Household composition is potentially a critical determinant of children's schooling and work activities. The number of household members may determine total labor availability to allocate to various market and domestic activities. The mean number of boys is 1.7, girls 1.4, women 1.7 and men 1.6.[20] Adult characteristics such as the ages of the household head and spouse are also included in the econometric analysis. These variables capture potential life-cycle influences of the primary decision makers who influence children's time allocation. The household's human capital is measured by parental education. Education is measured as an indicator variable of the parent ever

[20] Adults include any person aged 18 or older in the household. This may not necessarily be congruent with the social conception of how households themselves may view members, since persons aren't usually considered adults until after marriage. However, for the purposes of investigating work, persons aged 18 have reached full physical development and are usually out of school to be freely allocated to different activities. Children aged 17 or under may still be developing and/or have obligations to school, which may differentially impact their time allocation.

having completed a grade level of education. Only 5 percent of mothers have any education whereas fathers have an education rate of 10 percent.[21]

Household assets and unearned income are reported in the second column of Table 3.3. Four types of assets are reported: herd size, herd value, agricultural capital value, and household durables value.[22] Herd size captures the number of animals that require supervision, resulting in higher child labor demand. However, herd value captures the value of animals as an asset. Hence, households may choose to store their wealth in fewer, high-value animals that are less liquid, or a larger number of low-value animals. Households have a mean of 19.25 animals with a value of 532,000 FCFA, slightly more than USD 1,000. Agricultural capital had much lower mean household value, less than USD 100, or 47,000 FCFA. Durable goods, which include furniture, radios, motorcycles, and other house wares, had a mean value of 303,000 FCFA, or less than USD 600. These assets represent varying levels of liquidity, which may affect whether households choose them to smooth consumption or choose instead to increase children's work. A primary component of unearned income is captured by migrant remittances that have a mean value of 40,508 FCFA, but with a high standard deviation across households.

The incidence of household shocks is summarized in Tables 3.3.A, 3.3.B and 3.6. Twenty-five percent of households reported a large crop shock caused by insects or birds eating pre-harvest crops, a common problem in northern Mali over which

[21] Parental education is potentially endogenous, but we have no plausible instruments, such as grandparent's education, to identify this relationship. The schooling participation of grandparents reported in the study is close to zero. Concerns about this source of potential endogeneity may be assuaged by the low incidence of parental education in these data.

[22] The value of all assets is reported in local currency, the CFA Franc (FCFA). During the period of the survey, US$ 1 = 515 FCFA approximately. Herd size is reported here as the total number of animals owned by the household.

farmers have limited control. Fifty-three percent of farmers reported no crop losses, while another 22 percent reported only minor crop losses. Households also reported which members had been sick in the previous month. Adult males had an illness incidence rate of 13 percent. Twenty-one percent of women reported that they were sick in the previous month, while 14 percent of children were reported to have been sick. The distribution of these shocks across the regions studied also provides evidence of the variability of their incidence in different zones. Table 3.6 shows that the incidence rates of large crop losses by *cercle* are highest in Rharous, Bourem, and Niafunke, with Rharous being particularly hard hit by crop losses in the last agricultural season.[23] The rates of male, female, and child sickness display a different regional distribution than the production shocks. The highest rates of male illness rates come from Rharous, Tombouctou, and Dire, while female illness rates are highest in Bourem, Tombouctou, and Dire. Children's illness rates are highest in Bourem, Rharous, and Tombouctou.

There are two types of community characteristics that are also included in the econometric specifications: characteristics that proxy for market development and the potential of children's work opportunities and school quality, and characteristics that increase the efficiency of children's learning, i.e., the cognitive skills attained per unit of time spent in school (Table 3.5). Table 3.4 presents the community characteristics that include whether the child comes from an urban or rural area, a regional indicator, and variables indicating whether the child's village or town has access to the Niger River or an improved road. Access to either the river or an improved road increases the commercial potential of a village or town because transportation and

[23] Despite the high incidence rates in Bourem, only seven percent of the villages surveyed come from this area, reflecting perhaps a more isolated incident than the percentage of households affected may seem to indicate if the sample were evenly distributed across the *cercles*.

communication links increase. Commune-level data is also collected to indicate the size of potential markets as a function of the commune's total population and the concentration of this population by the number of villages per commune. These community characteristics may have alternative effects on the allocation of children's time across different activities. Greater access to income-generating activities may increase the child's market-oriented work as households struggle to meet subsistence requirements. Alternatively, access to income-generating activities may cause adults to work more, decreasing children's market-oriented work, but increasing their domestic work as adults leave the household to pursue income opportunities. Exactly how these income and substitution effects, both on children and adults, affect the allocation of children's time to different activities is an empirical question.

Table 3.4: Descriptive Statistics: Community Characteristics

Variable	Obs.	Mean	Std. Dev.
Regional Characteristics and Distribution			
Urban	151	0.086	0.281
River Access	151	0.331	0.472
Regional Indicators			
Niafunke	151	0.377	0.486
Goundam	151	0.166	0.373
Dire	151	0.159	0.367
Tombouctou	151	0.099	0.300
Rharous	151	0.073	0.261
Bourem	151	0.119	0.325
Kidal	151	0.007	0.081
Access to Roads			
Road Connects with Village	151	0.139	0.347
within 1-10km	151	0.417	0.495
within 11-20km	151	0.232	0.423
more than 20km	151	0.212	0.410

Table 3.4 (Continued)

Variable	Obs.	Mean	Std. Dev.
Commune Population			
less than 5000	151	0.093	0.291
5001-10000	151	0.225	0.419
10001-20000	151	0.391	0.490
20001-30000	151	0.146	0.354
more than 30000	151	0.146	0.354
Villages per Commune			
Less than 10	151	0.152	0.361
11-20	151	0.205	0.405
21-30	151	0.285	0.453
more than 30	151	0.358	0.481

Table 3.5: School Characteristics

Primary School Characteristics			
Variable	Obs.	Mean	Std. Dev.
No Primary School Access	151	0.258	0.439
Primary School in Village	151	0.563	0.498
less than 5 km	151	0.099	0.300
greater than 5 km	151	0.079	0.271
Multiple Primary Schools in Village	151	0.132	0.395
Student-Teacher Ratio--Primary	107	45.496	20.418
Repetition Rate—Primary	98	0.305	0.148
Boys Exam Pass Rate--Primary	71	0.651	0.266
Girls Exam Pass Rate--Primary	67	0.590	0.325
Secondary School Characteristics			
Secondary School in Village	151	0.159	0.367
High School Characteristics			
High School in Village	151	0.026	0.161

Table 3.6: Distribution of Shocks by Region

Region	Male Illness	Female Illness	Child Illness	Small Crop Shocks	Large Crop Shocks
Niafunke	0.107	0.082	0.082	0.138	0.198
Goundam	0.079	0.041	0.011	0.185	0.166
Dire	0.183	0.165	0.018	0.064	0.009
Tombouctou	0.270	0.255	0.102	0.153	0.163
Rharous	0.329	0.146	0.195	0.000	0.890
Bourem	0.071	0.503	0.420	0.330	0.260

VI. Estimation Results

The effects of household characteristics—assets and household composition, parental and child characteristics, community characteristics such as school quality, and crop and health shocks—on participation across schooling, home production, and market-oriented production[24] are presented in this section. All reported coefficients in the tables are marginal effects.

Probit Model with Random Effects

Tables 3.7 and 3.8 present the results from the random effects model.[25] Gender has significant impacts on the selection of children into farm work, family business activities, and child care. Joint production of market work and schooling for boys also becomes significant at the 10 percent level after controlling for random effects. Boys

[24] The outcome variables we consider include indicators for school, farm work, working in the family business, domestic work, watching other children, and three joint-production categories: market production and school, home production and school, and market production and home production. Full regression results are presented in Tables 3.7-3.18.

[25] The domestic work equation has been dropped because its high positive response rate made the random effects estimation unable to converge.

are more likely to engage in farm work and joint production of market work and schooling. However, boys are less likely to engage in work in the family business and child care activities. As expected, age effects are positive for schooling at age 11 and negative for older children (16 and 17 year olds).

Table 3.7: Probit—Random Effects

	School	Farm	Family Business	Childcare
Boy Indicator				
	0.036	2.022***	-0.470**	-0.812***
	(0.137)	(0.176)	(0.237)	(0.178)
Ages				
age11	0.418*	0.296	-0.007	0.295
	(0.249)	(0.268)	(0.434)	(0.317)
age12	0.013	0.496**	0.513	0.321
	(0.201)	(0.214)	(0.342)	(0.275)
age13	0.271	0.047	0.010	0.233
	(0.235)	(0.245)	(0.422)	(0.296)
age14	-0.118	0.153	0.071	0.013
	(0.214)	(0.219)	(0.345)	(0.275)
age15	-0.502**	0.824***	1.054**	0.048
	(0.240)	(0.245)	(0.434)	(0.285)
age16	-0.677***	0.263	0.703*	-0.171
	(0.223)	(0.220)	(0.377)	(0.281)
age17	-1.128***	0.451*	0.423	0.236
	(0.274)	(0.269)	(0.409)	(0.320)
Household Composition				
Biological child indicator	0.365*	-0.005	-0.519	-0.530**
	(0.193)	(0.193)	(0.355)	(0.244)
Number of girls	0.064	-0.218***	-0.016	0.594***
	(0.073)	(0.080)	(0.189)	(0.121)
Number of boys	0.042	-0.103	-0.102	0.221**
	(0.066)	(0.066)	(0.142)	(0.089)
Number of adult men	-0.102	0.0736	-0.336*	-0.473***
	(0.086)	(0.084)	(0.173)	(0.119)
Number of adult women	0.067	0.14	0.00848	-0.181
	(0.091)	(0.094)	(0.192)	(0.124)

Table 3.7 (Continued)

	School	Farm	Family Business	Childcare
Household Assets and Unearned Income				
Livestock Value (FCFA)	0.034**	-0.013	-0.023	-0.035
	(0.015)	(0.017)	(0.036)	(0.027)
Herd Size (Number of Animals)	-0.011*	0.010	-0.009	0.006
	(0.007)	(0.007)	(0.015)	(0.010)
Agricultural Capital (FCFA)	0.006	0.012	0.000	0.016
	(0.011)	(0.012)	(0.020)	(0.019)
Household Durables (FCFA)	0.005	-0.027	0.007	0.011
	(0.009)	(0.020)	(0.007)	(0.019)
Migrant Remittances (FCFA)	-0.062*	-0.067	-0.017	-0.022
	(0.035)	(0.049)	(0.056)	(0.070)
Parental Characteristics				
Any Mother's Education	1.170***	0.314	2.215**	1.598***
(1=Yes)	(0.346)	(0.374)	(0.892)	(0.533)
Any Father's Education	1.024***	-0.288	-1.950***	-0.079
(1=Yes)	(0.267)	(0.282)	(0.624)	(0.381)
Age of HH Head	-0.004	0.005	-0.017	0.017***
	(0.004)	(0.005)	(0.010)	(0.006)
Age of HH Head's spouse	0.005	-0.012*	0.029*	0.001
	(0.006)	(0.006)	(0.015)	(0.008)
Community Characteristics				
Access to River	-0.32	-1.073***	1.198**	-0.133
(1=Yes)	(0.291)	(0.294)	(0.592)	(0.379)
Roads				
within 1-10km	0.036	0.714**	0.469	1.674***
	(0.325)	(0.307)	(0.656)	(0.452)
within 11-20km	0.395	0.441	-0.182	1.014**
	(0.419)	(0.378)	(0.901)	(0.514)
greater than 20km	0.564	1.447***	2.199*	2.029***
	(0.446)	(0.449)	(1.190)	(0.591)
School Characteristics				
Primary School in Village	2.261***	-0.065	3.167**	-0.208
	(0.617)	(0.506)	(1.266)	(0.690)

Table 3.7 (Continued)

	School	Farm	Family Business	Childcare
Primary School within 1-5km	0.570	0.082	2.893*	-1.178
	(0.774)	(0.588)	(1.493)	(0.773)
Primary School farther than 5km	-0.250	-0.234	3.467**	-0.447
	(0.859)	(0.715)	(1.639)	(0.937)
Multiple Primary Schools	0.084	0.012	0.148	0.324
(1=Yes)	(0.335)	(0.296)	(0.647)	(0.394)
Student-Teacher Ratio	-0.014**	-0.000	-0.035**	-0.010
	(0.007)	(0.007)	(0.016)	(0.009)
Repetition Rate	-0.554	0.553	2.458	1.955*
	(0.747)	(0.761)	(1.764)	(1.029)
Exam Pass Rate-Boys	0.261	-0.458	-1.084	-0.704
	(0.619)	(0.605)	(1.767)	(0.849)
Exam Pass Rate-Girls	0.201	-0.199	-0.296	-0.888
	(0.580)	(0.582)	(1.638)	(0.817)
Secondary School in Village	0.961***	-0.655**	-1.403**	0.021
	(0.274)	(0.279)	(0.669)	(0.387)
High School in Village	0.602	-0.013	-0.94	2.872***
	(0.490)	(0.499)	(1.289)	(0.692)
Constant	-2.187***	-2.543***	6.217***	-2.955***
	(0.828)	(0.778)	(1.932)	(1.082)
Observations	1859	1859	1859	1859
Number of hid	1045	1045	1045	1045

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3.8: Children's Joint Production: Probit—Random Effects

	Market Production and School	Home Production and School	Market and Home Production
Boy Indicator			
	0.309**	-0.087	0.311
	(0.151)	(0.138)	(0.206)
Ages			
age11	-0.094	0.461*	0.051
	(0.285)	(0.251)	(0.383)
age12	-0.130	0.240	0.356
	(0.226)	(0.206)	(0.333)
age13	-0.004	0.421*	-0.002
	(0.260)	(0.237)	(0.340)
age14	-0.323	0.030	-0.168
	(0.235)	(0.216)	(0.355)
age15	-0.481*	-0.364	0.224
	(0.268)	(0.242)	(0.340)
age16	-0.697***	-0.401*	-0.227
	(0.246)	(0.223)	(0.334)
age17	-1.414***	-1.071***	-0.108
	(0.324)	(0.290)	(0.382)
Household Composition			
Biological child indicator	0.245	0.124	-0.174
	(0.218)	(0.193)	(0.288)
Number of girls	0.001	0.115	-0.023
	(0.088)	(0.074)	(0.123)
Number of boys	0.052	0.062	-0.156
	(0.079)	(0.067)	(0.117)
Number of adult men	-0.169	-0.163*	-0.178
	(0.106)	(0.090)	(0.146)
Number of adult women	0.136	0.012	0.016
	(0.108)	(0.093)	(0.160)
Household Assets and Unearned Income			
Livestock Value (FCFA)	0.007	0.023	-0.028
	(0.019)	(0.016)	(0.034)
Herd Size (Number of Animals)	0.001	-0.012*	0.015
	(0.008)	(0.007)	(0.011)

Table 3.8, (Continued)

	Market Production and School	Home Production and School	Market and Home Production
Agricultural Capital (FCFA)	0.013		
	(0.014)	(0.011)	(0.018)
Household Durables (FCFA)	0.008	0.019	-0.037
	(0.010)	(0.013)	(0.040)
Migrant Remittances (FCFA)	-0.080*	-0.119***	-0.115
	(0.046)	(0.045)	(0.146)
Any Mother's Education	0.824**	1.227***	2.434***
(1=Yes)	(0.395)	(0.342)	(0.621)
Any Father's Education	0.840***	0.695***	-1.238**
(1=Yes)	(0.313)	(0.260)	(0.557)
Age of HH Head	-0.005	-0.004	0.002
	(0.005)	(0.004)	(0.008)
Age of HH Head's spouse	0.003	0.010	0.019*
	(0.008)	(0.007)	(0.011)
Community Characteristics			
Access to River	-0.129	0.022	-1.400**
(1=Yes)	(0.356)	(0.289)	(0.583)
Roads			
within 1-10km	0.210	-0.190	2.362***
	(0.399)	(0.324)	(0.599)
within 11-20km	0.503	0.013	1.539**
	(0.513)	(0.423)	(0.689)
greater than 20km	0.575	0.472	2.714***
	(0.539)	(0.443)	(0.777)
School Characteristics			
Primary School in Village	2.855***	2.857***	1.599*
	(0.749)	(0.637)	(0.936)
Primary School within 1-5km	0.169	0.949	0.850
	(1.017)	(0.785)	(0.986)
Primary School farther than 5km	1.145	0.502	1.024
	(1.045)	(0.877)	(1.364)
Multiple Primary Schools	-0.091	0.030	0.180
(1=Yes)	(0.417)	(0.336)	(0.527)
Student-Teacher Ratio	-0.026***	-0.019***	-0.032**
	(0.008)	(0.007)	(0.014)
Repetition Rate	0.177	-0.933	2.396
	(0.904)	(0.756)	(1.484)

Table 3.8 (Continued)

	Market Production and School	Home Production and School	Market and Home Production
Exam Pass Rate-Boys	-0.582	0.236	0.076
	(0.775)	(0.645)	(1.186)
Exam Pass Rate-Girls	0.513	-0.262	-1.877
	(0.729)	(0.607)	(1.239)
Secondary School in Village	0.820**	0.269	-1.530**
	(0.328)	(0.272)	(0.639)
High School in Village	1.158*	1.025**	2.476**
	(0.605)	(0.494)	(0.986)
Constant	-3.002***	-2.206***	-7.822***
	(1.006)	(0.835)	(1.586)
Observations	1859	1859	1859
Number of hid	1045	1045	1045

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Household characteristics and composition are also important determinants of children's participation in work and schooling activities.[26] Controlling for random effects, the probability of being selected into schooling increases by .365 for biological children,[27] indicating that foster or adopted children may not receive the same investments in human capital. The number of boys, girls, and adults in the household determines the household's labor availability. The higher the number of girls, the lower the probability that they will be selected for farm work, but the higher

[26] The number of children within the household and whether the child is fostered into the household may be endogenous, even controlling for household random effects. We relax this assumption later and perform a robustness check on the stability of the coefficients without these variables included in the regression.

[27] This suggests that foster or adopted children may not receive uniform investments in human capital, but the causality may not be directly related to foster parents. If birth parents have already withheld children from enrolling in school, it may be prohibitively costly or impossible for foster parents to reverse this decision. See for example, Akresh (2007a and 2007b) on the decision to foster and the impact of foster on children's schooling.

the probability that they will be selected for childcare. An increase in the number of boys also increases the probability that a child will be selected into childcare. Higher numbers of adult men in the household lowers the selection of children into all work activities except farm work.

Household assets are less important factors of selection into children's work and schooling activities. For selection into schooling, herd value positively affects schooling participation, while herd size negatively affects it. These marginal effects suggest that livestock has dual implications for the household; as a store of wealth which requires supervision and a task that may increase the demand for child labor. Hence, livestock holdings influence the internal mechanisms of both household labor demand and asset accumulation strategy to mitigate risk.

Parental education has large and significant effects on children's work and schooling. Children of educated fathers have higher selection probabilities into schooling and lower selection probabilities into the family business and joint market and home production. However, children of educated fathers face higher selection probabilities for the other two joint production variables. Mother's education has significant effects for all activities except farming. This suggests that educated parents may have increased income-generating opportunities that require not only additional labor from their children in market-oriented activities, but also in home production. This hypothesis is reinforced by the finding that children of educated mothers have higher selection probabilities into joint production.

Examining the commune-level demographic and school characteristics data, the presence of a primary school in a village increases the probability that a child is selected into schooling. In the random effects specification, the presence of a secondary school also increases this probability. The latter may reflect parents' expectations that having their child finish high school would provide a higher return than stopping at primary education. The presence of a primary school also increases participation in joint production, both market-oriented and home production with schooling, as well as in domestic work and family business work. The latter two are time-insensitive activities that can accommodate schedules outside of school hours. School quality characteristics also influence selection into school. For example, an increased student teacher ratio in primary schools lowers selection into schools by .014. In most villages, only one school exists which minimizes concerns that school choice could be explaining variation in child labor and schooling outcomes. In the next section, production and health shocks are used to identify labor substitution patterns within the household.

Impact of Health and Crop Loss Shocks on Children's Work and Schooling

Before estimating the effects of production and morbidity shocks on child labor and schooling variables, the exogeneity test described by Equation 22 was conducted. Table 3.9 reports these results. The probability that a production or morbidity shock was reported does not increase with parental education in this sample. Reporting of large production shocks actually decreases with parental education by 8 percent for mothers and 6 percent for fathers. Some asset variables are correlated with production shocks and male morbidity. However, all but one of the four significant coefficients is greater than .01 and over half are actually negative. Seasonal indicators that potentially control for the timing of the interview to the recall period for the shock, are only positive in the reporting of child morbidity shocks during the harvest period. The harvest period indicator increases the probability a child illness shock is reported by .1. Despite a few correlations, there is not a strong argument for the endogenity of these reported shocks based on observable household characteristics within this sample.

Table 3.9: Determinants of the Incidence of Shocks

	Large Production Shocks	Small Production Shocks	Adult Male Sick	Adult Female Sick	Child Sick
Household Composition					
Number of girls	0.004	-0.004	0.003	0.034***	0.025***
	(0.012)	(0.014)	(0.010)	(0.011)	(0.009)
Number of boys	0.022**	-0.002	0.008	0.007	0.017**
	(0.011)	(0.011)	(0.007)	(0.009)	(0.007)
Number of adult men	0.014	0.007	0.001	0.022**	0.017**
	(0.012)	(0.012)	(0.010)	(0.011)	(0.008)
Number of adult women	0.051***	-0.005	-0.002	0.005	-0.027***
	(0.016)	(0.012)	(0.011)	(0.012)	(0.010)
Household Assets					
Livestock Value (FCFA)	-0.011***	0.009***	0.001	0.006	0.001
	(0.004)	(0.003)	(0.002)	(0.004)	(0.002)
Herd Size (Number of Animals)	0.001	-0.001	-0.002***	-0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Agricultural Capital (FCFA)	0.001	-0.001	0.001	0.000	-0.003
	(0.002)	(0.001)	(0.001)	(0.001)	(0.015)
Household Durables (FCFA)	-0.004	0.001	-0.004	-0.006*	-0.001
	(0.004)	(0.000)	(0.003)	(0.003)	(0.001)
Migrant Remittances (FCFA)	-0.004	0.002	-0.023*	0.018**	0.007**
	(0.007)	(0.003)	(0.013)	(0.008)	(0.003)
Parental Education					
Any Mother's Education (1=Yes)	-0.084**	0.015	-0.010	0.038	0.015
	(0.042)	(0.056)	(0.037)	(0.070)	(0.034)
Any Father's Education (1=Yes)	-0.058*	0.076	0.003	0.010	-0.026
	(0.033)	(0.047)	(0.038)	(0.039)	(0.021)
Age of HH Head	-0.001	-0.003***	0.000	0.004***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age of HH Head's spouse	0.002**	0.003***	0.002***	-0.002***	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Table 3.9 (Continued)

	Large Production Shocks	Small Production Shocks	Adult Male Sick	Adult Female Sick	Child Sick
Community Characteristics					
Access to River	-0.227***	-0.006	-0.025	-0.029	0.040
(1=Yes)	(0.061)	(0.064)	(0.043)	(0.056)	(0.033)
Season Interviewed					
Post-harvest	-0.097	-0.053	0.101	0.082	-0.030
	(0.070)	(0.103)	(0.095)	(0.086)	(0.041)
Harvest	-0.034	0.033	0.007	0.076	0.103**
	(0.052)	(0.074)	(0.033)	(0.051)	(0.049)
Observations	1859	1859	1859	1859	1859

Notes: Robust standard errors are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Controlling for random effects, the effects of shocks are statistically significant for agricultural shocks and health shocks to women making participation decisions across schooling and work activities. Table 3.10 presents the results of the probit model with random effects and shocks. Large and small crop shocks induce higher participation by children in farm work. Both types of crop shocks decrease the probability of working in the family business, with large crop losses having much larger magnitudes than small crop losses. A large crop loss increases the child's probability they will be withdrawn from school, while significantly decreasing children's participation in providing childcare to other children and the joint production of market and schooling activities. Small crop losses increase children's childcare to other children in the household, but the effect is opposite for large crop losses. This may confirm the hypothesis that adults, when fully occupied responding to smaller crop losses, leave children to increasingly care for themselves in these minor crises. However, as the magnitude of the shock increases, the household may be forced to mobilize all available labor to either salvage a harvest quickly or replant before the rainy season passes completely.

Table 3.10.A: Marginal Effects of Shocks on Children's Participation in Work and School

	Withdrawn from School	Farm Work	Family Business	Child Care	Market-School	Home-School	Market-Home
Large Crop Loss	2.049**	1.046***	-4.826***	-0.603	-0.853**	-0.413	-0.495
	(1.026)	(0.293)	(0.754)	(0.395)	(0.366)	(0.300)	(0.511)
Small Crop Loss	0.315	0.809***	-1.469*	0.549	0.615*	0.401	-0.04
	(0.882)	(0.274)	(0.779)	(0.384)	(0.328)	(0.275)	(0.481)
Adult Male Sick	0.709	0.283	-0.296	0.0229	0.065	0.342	-0.304
(1=Yes)	(0.853)	(0.280)	(0.814)	(0.364)	(0.326)	(0.272)	(0.497)
Adult Female Sick	1.506*	0.207	2.424***	0.849*	0.228	0.37	2.051***
(1=Yes)	(0.869)	(0.297)	(0.742)	(0.445)	(0.346)	(0.286)	(0.599)
Child Sick	-0.212	-0.133	-1.246	-0.0326	-0.122	-0.143	0.308
(1=Yes)	(0.966)	(0.327)	(0.821)	(0.464)	(0.392)	(0.324)	(0.620)
Observations	761	1859	1859	1859	1859	1859	1859
Number of households	483	1045	1045	1045	1045	1045	1045

Notes: All coefficients are marginal effects. All covariates are estimated in the regression, but only the shock results are displayed. Absolute value of z statistics are in parentheses. * significant at 10% ** significant at 5%; *** significant at 1%

Table 3.10.B: Multivariate Probit Estimates

	Withdrawl	Farm Work	Family Business	Child Care
Large Crop Loss	0.832***	1.010***	-1.045***	-0.903*
	(0.290)	(0.312)	(0.324)	(0.504)
Small Crop Loss	0.257	0.643**	0.178	-0.41
	(0.266)	(0.299)	(0.239)	(0.309)
Adult Male Sick	0.412	0.213	0.305	0.254
(1=Yes)	(0.369)	(0.243)	(0.367)	(0.231)
Adult Female Sick	0.545**	0.12	0.736***	0.611**
(1=Yes)	(0.243)	(0.224)	(0.264)	(0.263)
Child Sick	-0.033	0.184	-0.248	0.100
(1=Yes)	(0.252)	(0.276)	(0.273)	(0.336)
Observations	761	761	761	761

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100,000 FCFA, roughly 200 US$. All covariates are estimated in the regression, but only the shock results are displayed. Absolute value of z statistics are in parentheses. * significant at 10% ** significant at 5%; *** significant at 1%.

Health shocks to women have large substitution effects on the participation of children across school and work activities[28]. A sick adult women in the household increases the probability that a child will be withdrawn from school, work in the family business, and that a child will watch other siblings. These results suggest that children are substitutes for women when female labor supply is reduced in the household by illness, as women's primary role in the household, apart from domestic tasks are small-scale family businesses that usually rely on household labor.

[28] A robustness check was conducted to verify whether differences in the definition of a health shock altered significantly the results. The current definition of the health shock is whether an individual reported being sick at all in the previous month. As a robustness check, at least a week of sickness was used in the analysis. The results were not significantly different, though a few of the variables were no longer significant. This may be because the incidence of illness is already small in the sample when the illness variable is constructed as being "sick at least one day in the past month". Because there is a higher tolerance for poor health someone who says they were sick may still understate the days they were sick or didn't work due to sickness. For this reason, the current construction of the health shock was maintained.

It is important to note in the interpretation of these coefficients that it is likely high substitution of child labor into income generating activities such as farming or the family business in the presence of shocks is caused in part to poor labor market integration in Northern Mali. Due to the spatial dispersion of the population and its low density, transportation costs are quite high between villages. Hiring in labor on short notice is difficult in rural areas. Even in larger towns, households will schedule seasonal laborers to meet labor demand at crucial times in the crop production cycle. Therefore, when shocks occur, mobilizing labor is most easily undertaken within the family.

Shock-Asset Interactions with Random Effects

Tables 3.11 and 3.12 present the results that investigate the role of assets in mitigating shocks, controlling for random effects. The value of asset stocks have significant effects when interacted with crop shocks. Higher levels of durable assets decrease the probability a child works on the farm in response to a large production shock. Agricultural capital interacted with the large crop loss shock lowers the selection of children into childcare or into the joint production of market and home production with schooling. Livestock values interacted with small crop losses increase child participation in joint market production and schooling. As noted in the discussion of the econometric specification above, a strictly causal interpretation is difficult without a detailed panel data set. However, these results are broadly consistent with the hypothesis that different asset types have varying interactions with child labor based on the ex-post responses available to the household who holds different portfolios of assets. For example, a household who holds high levels of agricultural capital has less labor intensive responses to production shocks which is reflect in the lower probabilities children are engaged in joint production activities. Durable assets reduce the probability a child works on the farm in response to idiosyncratic production shocks because the household faces fewer liquidity constraints in hiring in labor. However, the magnitude of the durable-shock interaction coefficients in comparison to the agricultural capital-shock coefficients are lower because poor labor market integration still constrains the household's response.

Table 3.11: Probit—Crop Shocks with Asset Interactions and Random Effects

	Withdrawn from School	Farm Work	Child Care	Market-School	Home-School	Market-Home
Durables x Large Crop Loss	-0.526	-0.135*	0.097	0.119	0.060	-0.032
	(0.356)	(0.076)	(0.109)	(0.108)	(0.107)	(0.143)
Durables x Small Crop Loss	-0.093	-0.078	-0.035	0.044	0.027	-0.334
	(0.345)	(0.062)	(0.033)	(0.054)	(0.046)	(0.215)
Agricultural Capital x Large Crop Loss	2.395	-0.025	-2.767***	-1.431*	-2.107**	-1.357
	(1.957)	(0.580)	(1.025)	(0.865)	(0.929)	(1.247)
Agricultural Capital x Small Crop Loss	0.886	-0.379	0.664	0.196	-0.338	-0.342
	(2.256)	(0.473)	(0.876)	(0.520)	(0.491)	(0.859)
Livestock Value x Large Crop Loss	-0.363	0.009	0.034	0.075	0.076	0.104
	(0.263)	(0.053)	(0.076)	(0.072)	(0.064)	(0.096)
Livestock Value x Small Crop Loss	-0.157	-0.037	-0.023	0.064**	0.012	0.041
	(0.131)	(0.028)	(0.048)	(0.032)	(0.026)	(0.058)
Observations	761	1859	1859	1859	1859	1859
Number of hid	483	1045	1045	1045	1045	1045

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interactions are displayed. Absolute value of z statistics are in parentheses. * significant at 10% ** significant at 5%; *** significant at 1%

Table 3.12: Probit—Health Shocks with Asset Interactions and Random Effects

	Withdrawn from School	Farm Work	Child Care	Market-School	Home-School	Market-Home
Durables x Sick Male	-0.365	-0.217**	-0.197*	-0.099	0.046	-0.350**
	(0.328)	(0.102)	(0.118)	(0.107)	(0.091)	(0.171)
Durables x Sick Female	0.409	0.063	-0.125	-0.105	-0.124	-0.184
	(0.313)	(0.097)	(0.144)	(0.124)	(0.113)	(0.237)
Durables x Sick Child	0.428	0.012	0.109	0.005	-0.030	-0.031
	(0.367)	(0.057)	(0.158)	(0.040)	(0.056)	(0.234)
Agricultural Capital X Sick Male	0.059	0.075	0.034	0.059	0.004	-0.008
	(0.480)	(0.059)	(0.114)	(0.094)	(0.062)	(0.150)
Agricultural Capital x Sick Female	0.702	0.067	1.253	1.212*	0.502	1.023
	(1.680)	(0.594)	(0.843)	(0.713)	(0.611)	(1.357)
Agricultural Capital x Sick Child	0.214	-0.101	-1.920*	-1.023	-0.467	-1.287
	(2.649)	(0.748)	(1.039)	(0.861)	(0.758)	(1.522)
Livestock Value x Sick Male	0.177	0.164***	0.157**	0.090	0.046	0.160*
	(0.149)	(0.063)	(0.070)	(0.057)	(0.049)	(0.090)
Livestock Value x Sick Female	-0.273	-0.093*	-0.073	0.085	0.143**	0.034
	(0.198)	(0.054)	(0.078)	(0.059)	(0.056)	(0.121)
Livestock Value X Sick Child	-0.334	-0.034	0.076	-0.032	-0.138**	0.022
	(0.345)	(0.068)	(0.096)	(0.061)	(0.057)	(0.126)
Observations	761	1859	1859	1859	1859	1859
Number of hid	483	1045	1045	1045	1045	1045

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100 000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interaction results displayed. Absolute value of z statistics are in parentheses. * significant at 10%, ** significant at 5%; *** significant at 1%

Assets are also fundamental to the household's ex-post response to health shocks. Durables stocks decrease the probability that a child works on the farm in response to the sickness of an adult male in the household. Durables also decrease selection into childcare and the joint activities of market and home production. When adult men fall ill, livestock values interacted with the shocks increase child participation in farming, childcare, and joint market and home production. When adult females fall ill, livestock values interacted with the shock increase participation in farm work, child care, and joint market production and schooling. This suggests that child labor and some asset types may be complementary, in contrast to the literature on consumption smoothing, which suggests assets help insure households against falling into poverty. While this may be true in the short term, if shocks induce households to withdraw children from school and assets provide no insurance against this response to shocks, lower human capital of children may lead to increased levels of future poverty. When adults fall ill, assets, specifically durables, are the only types of assets that insure children against higher participation in market and home production activities.

Verifying the Assumptions of the Random Effects Estimator

The assumptions of strict exogeneity, independence of dependent variables conditioned on the unobservable effect and independent variables, and independence of the independent variables and the unobservable effect are strong. But these assumptions are necessary given the extensive literature that suggests that household effects such as parental education and assets influence child labor and schooling participation. While likelihood ratio tests that the unobserved effect is absent were rejected in all equations at the 5 percent significance level, this only confirms the presence of an unobservable, not the conditions under which it can consistently estimate the parameters.

Using a small subset of child panel data with observations from 1997 and 2006, estimates of Equation 23 are reported in Table 3.13. While sickness data for all household members from 1997 is not available, crop loss shock data is available. If strict exogeneity is violated, coefficients from crop loss shocks in 1997 should have significant effects. However, this is not the case in the data. Asset-shock interactions for 1997 are also not significant in regression results. While this evidence supports the strict exogeneity hypothesis, the absence of significant effects may be due to the relatively small sample size rather than the actual absence of a lagged effect.

Table 3.13: Panel Estimates

	School	Farm	Family Business	Child Care
Large Crop Loss 2006	0.0003**	-0.069	0.076	-0.366***
	(.000)	(0.273)	(0.115)	(0.135)
Large Crop Loss 1997	6.60E-07	0.043	-0.305	-0.053
	(0.000)	(0.076)	(0.227)	(0.206)
Asset-Shock Interaction 2006	-5.50E-06***	0.099***	0.043**	-0.112***
	(0.000)	(0.019)	(0.020)	(0.042)
Asset-Shock Interaction 1997	6.65E-08	-0.0613	0.115**	-0.05
	(0.000)	(0.099)	(0.048)	(-.085)
Observations	186	186	186	186

Notes: Regression controls for gender, ethnicity, and parent's education. Robust standard errors in parentheses are clustered at the village level.
* significant at 10%; ** significant at 5%; *** significant at 1%

To provide additional evidence for the strict exogeneity hypothesis, the sample was disaggregated according to younger (ages 10-13) and older (ages 14-17) cohorts using the full cross-section. If strict exogeneity is violated, there should be distinct differences in parameter estimates for asset stocks and household composition variables if changes in these variables in subsequent periods have persistent effects on current child time allocation. Presumably, the older cohort would have been exposed to more of these lagged changes, which would result in systematic differences between the two cohorts. However, this pattern does not appear in the sample[29]. Parameter estimates, especially for assets, have small differences in magnitude and do not differ in significance across cohorts.

Pooling Child Labor and Schooling Equations by Gender

Given the importance of gender in our initial estimates of child labor and schooling, the sample was disaggregated to evaluate differences in parameter estimates by gender and the pooling of girls and boys. These results are presented in Tables 3.14.A and 3.14.B. Differences between boys and girls are most pronounced in the schooling participation equation. Girls that are biological children of the head of household are 50 percent more likely to attend school than girls who are not biological children. Asset values measured either by livestock value or durable goods increase boys' school participation by 5-6 percent per increase of 100 000 FCFA, while assets have no effect on girls' schooling. Parental education also has differential impacts on girls and boys. Any mother's education increases by 69 percent the selection probability on boys' schooling than for girls' schooling. Any father's education has a 53 percent

[29] These regression results are available on request, but are suppressed for brevity.

greater impact on girls. Despite these differences in magnitude, having either an educated mother or father greatly increases the child's probability of attending school.

Table 3.14.A: Participation Equations Controlling for Household Random Effects, Disaggregated by Gender

Sample Restriction	School Girls	School Boys	School Difference	Farm Girls	Farm Boys	Farm Difference
Household Composition						
Biological child indicator	0.762**	0.195	0.567	-0.055	-0.496	0.441
	(0.338)	(0.237)		(0.487)	(0.491)	
Number of girls	-0.021	0.111	-0.132	-0.257	-0.325*	0.068
	(0.117)	(0.086)		(0.198)	(0.194)	
Number of boys	0.018	0.042	-0.0234	0.086	-0.383**	0.469
	(0.105)	(0.074)		(0.174)	(0.172)	
Number of adult men	-0.071	-0.177*	0.106	0.007	0.202	-0.195
	(0.137)	(0.093)		(0.228)	(0.218)	
Number of adult women	-0.024	0.117	-0.141	0.260	0.221	0.039
	(0.136)	(0.105)		(0.264)	(0.269)	
Household Assets and Unearned Income						
Livestock Value (FCFA)	0.022	0.066**	-0.045	-0.044	-0.020	-0.024
	(0.023)	(0.026)		(0.038)	(0.033)	
Herd Size (Number of Animals)	-0.015	-0.012	-0.002	0.036**	0.021	0.015
	(0.011)	(0.009)		(0.016)	(0.015)	
Agricultural Capital (FCFA)	-0.013	-0.000	-0.013	-0.156	0.075	-0.231
	(0.035)	(0.010)		(0.348)	(0.079)	

Table 3.14.A (Continued)

Sample Restriction	School Girls	School Boys	School Difference	Farm Girls	Farm Boys	Farm Difference
Household Durables (FCFA)	0.006	0.043	-0.038	-0.062	-0.011	-0.051
	(0.009)	(0.029)		(0.065)	(0.016)	
Migrant Remittances (FCFA)	-0.090*	-0.038	-0.052	-0.066	-0.176*	0.110
	(0.051)	(0.043)		(0.118)	(0.107)	
Adult Characteristics						
Any Mother's Education (1=Yes)	0.975*	1.592***	-0.617	1.537	-0.183	1.720
	(0.530)	(0.429)		(0.936)	(0.835)	
Any Father's Education (1=Yes)	1.500***	0.619**	0.881	-0.716	-0.541	-0.175
	(0.448)	(0.293)		(0.755)	(0.687)	
Age of HH Head	-0.002	-0.008*	0.006	0.007	0.012	-0.005
	(0.007)	(0.005)		(0.012)	(0.011)	
Age of HH Head's spouse	0.013	0.006	0.008	-0.016	-0.027	0.010
	(0.010)	(0.007)		(0.016)	(0.017)	
School Characteristics						
Primary School in Village	2.393**	2.120***	0.273	0.593	-2.121	2.714
	(1.005)	(0.716)		(1.363)	(1.317)	
Secondary School in Village	0.176	1.252***	-1.076	-0.886	-0.986	0.100
	(0.434)	(0.324)		(0.724)	(0.648)	
High School in Village	1.213	-0.238	1.451	0.388	-0.375	0.763
	(0.813)	(0.552)		(1.402)	(1.148)	
Observations	833	1026		833	1026	
Number of hid	629	704		629	704	

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3.14.B: Participation Equations Controlling for Household Random Effects, Disaggregated by Gender

	Family Business			Child Care		
Sample Restriction	Girls	Boys	Difference	Girls	Boys	Difference
Household Composition						
Biological child indicator	-1.152*	0.365	-1.517	-1.187*	-0.676	-0.511
	(0.647)	(0.547)		(0.666)	(0.432)	
Number of girls	-0.367	0.029	-0.396	1.094***	0.692***	0.402
	(0.353)	(0.246)		(0.328)	(0.191)	
Number of boys	0.209	-0.030	0.239	0.582**	0.152	0.43
	(0.226)	(0.189)		(0.260)	(0.142)	
Number of adult men	-0.0364	-0.611***	0.5746	-0.975**	-0.604***	-0.371
	(0.297)	(0.212)		(0.442)	(0.174)	
Number of adult women	-0.358	0.507	-0.865	-0.690**	-0.015	0.705
	(0.380)	(0.310)		(0.310)	(0.192)	
Household Assets and Unearned Income						
Livestock Value (FCFA)	-0.021	-0.076*	-0.097	-0.040	-0.082*	-0.122
	(0.053)	(0.043)		(0.061)	(0.049)	
Herd Size (Number of Animals)	-0.021	-0.001	-0.020	-0.012	0.026	-0.039
	(0.023)	(0.016)		(0.027)	(0.017)	
Agricultural Capital (FCFA)	0.021	0.001	0.020	0.048	0.015	0.033
	(0.051)	(0.021)		(0.040)	(0.022)	
Household Durables (FCFA)	0.008	0.012	-0.005	0.039	0.016	0.023
	(0.008)	(0.010)		(0.046)	(0.038)	
Migrant Remittances (FCFA)	-0.088	0.102	-0.190	-0.107	-0.036	-0.072
	(0.120)	(0.065)		(0.147)	(0.128)	

Table 3.14.B (Continued)

	Family Business			Child Care		
Sample Restriction	Girls	Boys	Difference	Girls	Boys	Difference
Adult Characteristics						
Any Mother's Education	2.976**	1.143	1.833	3.190**	2.807***	0.383
(1=Yes)	(1.399)	(1.025)		(1.407)	(0.925)	
Any Father's Education	-2.175**	-1.316	-0.859	0.196	-0.795	0.991
(1=Yes)	(1.056)	(0.841)		(0.931)	(0.614)	
Age of HH Head	-0.026	-0.010	-0.015	0.031*	0.025**	0.006
	(0.016)	(0.014)		(0.017)	(0.010)	
Age of HH Head's spouse	0.043*	0.022	0.021	-0.003	0.001	-0.004
	(0.024)	(0.020)		(0.021)	(0.014)	
School Characteristics						
Primary School in Village	5.241**	2.147	3.094	-0.507	0.351	-0.858
	(2.213)	(1.585)		(1.821)	(1.075)	
Secondary School in Village	-0.969	-1.295	0.326	-0.540	0.829	-1.369
	(1.111)	(0.795)		(1.000)	(0.636)	
High School in Village	0.286	-1.891	2.177	6.395***	3.326***	3.069
	(2.113)	(1.697)		(1.811)	(1.098)	
Observations	833	1026		833	1026	
Number of hid	629	704		629	704	

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Robustness Check: Family Composition

Because of additions of new family members either through fostering or new child births, family composition variables should be considered endogenous in a structural model of household decision-making. These data do not contain plausible instruments to correct for the possible correlation between family composition variables and unobservables. To test whether this potential endogeneity affects parameter estimates, the previous probit model with household level random effects is re-estimated by omitting various combinations of the family composition variables to test the stability of the parameters[30]. The parameters of assets, parental education, gender, age effects, and community characteristics are stable across various combinations of assumptions about the family composition variables. All variables that had previously been significant remained significant with parameter estimates that were within reasonable levels of variation.

Controlling for Village-Level Fixed and Random Effects

An alternative to the household level random effects model previously estimated is to assume that there are no household-level effects, but only village-level effects that influence child time allocation. These village effects could be social norms or political influence. Social norms may affect whether children are encouraged to go to school as a result of the village overriding parental preferences that may differ with the norm. Political influence may determine whether the village is able to attract public investment such as schools, roads, or market location, which affects children's opportunity costs of attending school and working.

Tables 3.15.A and 3.15.B present the results under the assumption of no village effects, village fixed effects, and village random effects. There are differences in both parameter estimates and the significance of parameters under these three assumptions. This suggests that appropriately specifying the equation of interest is quite important to the empirical results. Regardless of specification, gender is a significant

[30] These regression results are available on request, but omitted for brevity.

determinant of participation with similar signs across the specifications, but different parameter estimates. The number of boys is significant under the random and fixed effects specification for schooling. For the farm fixed effects specification the number of boys remains significant, but is insignificant under the random effects specification. Village random effects also suggest significance at the 1 percent level for mother's and father's education, whereas fixed effects only capture a significant effect for father's education. The parameter estimates in the fixed effects specification are also quite similar to the no effects specification.

Table 3.15.A: Comparison of No Village Level Effects, Fixed Effects and Random Effects Estimates

	School			Farm		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Boy Indicator	-0.008	-0.045	0.014	0.412***	0.499***	1.048***
	(0.038)	(0.060)	(0.087)	(0.053)	(0.069)	(0.084)
Household Composition						
Biological child indicator	0.053	0.033	0.122	0.069	0.041	0.040
	(0.041)	(0.063)	(0.099)	(0.046)	(0.056)	(0.092)
Number of girls	0.013	0.024	0.020	-0.048***	-0.046**	-0.073**
	(0.013)	(0.019)	(0.033)	(0.015)	(0.021)	(0.031)
Number of boys	0.0035	0.043**	0.052*	-0.038**	-0.038*	-0.035
	(0.012)	(0.018)	(0.029)	(0.016)	(0.022)	(0.026)
Number of adult men	-0.015	-0.016	-0.071*	0.023	0.037	0.028
	(0.014)	(0.022)	(0.038)	(0.017)	(0.023)	(0.033)
Number of adult women	0.009	-0.017	0.018	0.062***	0.067***	0.050
	(0.020)	(0.030)	(0.040)	(0.021)	(0.024)	(0.036)

Table 3.15.A (Continued)

	School			Farm		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Household Assets and Unearned Income						
Livestock Value (FCFA)	0.007**	0.004	0.014**	-0.002	-0.010*	-0.007
	(0.003)	(0.004)	(0.007)	(0.004)	(0.005)	(0.006)
Herd Size (Number of Animals)	-0.001	-0.000	-0.005	0.002*	0.003	0.003
	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)
Agricultural Capital (FCFA)	0.002	0.002	0.001	0.002**	0.004***	0.007
	(0.001)	(0.002)	(0.005)	(0.001)	(0.001)	(0.005)
Household Durables (FCFA)	0.001	0.002	0.005	-0.006	-0.006	-0.008
	(0.001)	(0.002)	(0.005)	(0.005)	(0.006)	(0.008)
Migrant Remittances (FCFA)	-0.008	-0.011	-0.026*	-0.026***	-0.032***	-0.033*
	(0.005)	(0.008)	(0.015)	(0.008)	(0.006)	(0.018)
Adult Characteristics						
Any Mother's Education	0.142	0.129	0.533***	-0.074	-0.093	0.139
(1=Yes)	(0.107)	(0.117)	(0.141)	(0.113)	(0.147)	(0.147)
Any Father's Education	0.128*	0.168**	0.515***	-0.068	-0.107	-0.231**
(1=Yes)	(0.070)	(0.081)	(0.107)	(0.064)	(0.075)	(0.109)
Age of HH Head	-0.000	-0.000	-0.002	0.001	0.002	0.003*
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Age of HH Head's spouse	0.002	0.004*	0.004	-0.004***	-0.005***	-0.006**
	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)
School Characteristics						
Primary School in Village	0.349***	-0.540***	1.128***	-0.097	-0.316***	-0.067
	(0.048)	(0.018)	(0.428)	(0.113)	(0.063)	(0.302)

Table 3.15.A (Continued)

	School			Farm		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Secondary School in Village	0.150**	-0.814***	0.451*	-0.047	0.355***	-0.306
	(0.059)	(0.021)	(0.233)	(0.066)	(0.083)	(0.196)
High School in Village	0.049	0.352***	0.446	0.128	0.216**	-0.346
	(0.104)	(0.070)	(0.474)	(0.152)	(0.106)	(0.399)
Observations	1859	1429	1859	1859	1708	1859

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3.15.B: Comparison of No Village Level Effects, Fixed Effects and Random Effects Estimates

	Family Business			Child Care		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Boy Indicator	-0.082***	-0.101***	-0.162	-0.156***	-0.185***	-0.347***
	(0.022)	(0.038)	(0.100)	(0.042)	(0.054)	(0.096)
Household Composition						
Biological child indicator	0.038	0.035	-0.111	-0.020	-0.070	-0.292***
	(0.036)	(0.064)	(0.107)	(0.050)	(0.075)	(0.105)
Number of girls	0.004	-0.002	-0.085**	0.097***	0.114***	0.216***
	(0.012)	(0.023)	(0.039)	(0.024)	(0.037)	(0.038)
Number of boys	-0.015	-0.010	0.012	0.053***	0.077***	0.058*
	(0.011)	(0.019)	(0.032)	(0.019)	(0.028)	(0.030)
Number of adult men	-0.012	0.005	-0.032	-0.050**	-0.086***	-0.184***
	(0.013)	(0.026)	(0.043)	(0.020)	(0.028)	(0.042)

Table 3.15.B (Continued)

	Family Business			Child Care		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Number of adult women	-0.000	-0.013	0.055	-0.038**	-0.046	-0.106**
	(0.017)	(0.034)	(0.048)	(0.018)	(0.031)	(0.046)
Household Assets and Unearned Income						
Livestock Value (FCFA)	-0.000	-0.001	-0.010*	-0.008	-0.008	-0.016
	(0.003)	(0.004)	(0.006)	(0.005)	(0.006)	(0.010)
Herd Size (Number of Animals)	-0.000	0.002*	0.001	0.001	0.004*	0.006
	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.004)
Agricultural Capital (FCFA)	-0.001	-0.001	0.003	0.003	0.004**	0.008
	(0.002)	(0.002)	(0.006)	(0.002)	(0.002)	(0.007)
Household Durables (FCFA)	0.000	0.001	0.002	0.003	0.003	0.006
	(0.000)	(0.001)	(0.002)	(0.003)	(0.003)	(0.007)
Migrant Remittances (FCFA)	0.005	0.008	0.013	-0.010	-0.009	-0.031
	(0.007)	(0.010)	(0.013)	(0.011)	(0.012)	(0.024)
Adult Characteristics						
Any Mother's Education	0.068	0.060	0.351**	0.078	0.146	0.785***
(1=Yes)	(0.058)	(0.117)	(0.163)	(0.109)	(0.121)	(0.183)
Any Father's Education	-0.107	-0.103	-0.227*	0.036	0.084	-0.021
(1=Yes)	(0.069)	(0.106)	(0.125)	(0.078)	(0.093)	(0.128)
Age of HH Head	-0.001	-0.002	-0.006***	0.002*	0.002	0.005**
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Age of HH Head's spouse	0.000	-0.002	0.006*	-0.000	-0.001	0.000
	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)

Table 3.15.B (Continued)

	Family Business			Child Care		
Unobservables Assumption	No effects	Village Fixed Effects	Village Random Effects	No effects	Village Fixed Effects	Village Random Effects
Primary School in Village	0.394**	0.297***	0.911	0.027	0.442***	0.052
	(0.165)	(0.111)	(0.655)	(0.147)	(0.076)	(0.433)
Secondary School in Village	-0.122	0.889***	-0.047	0.000	0.374***	0.199
	(0.083)	(0.027)	(0.455)	(0.078)	(0.114)	(0.285)
High School in Village	-0.042	0.445***	-0.408	0.549***	0.103	1.774***
	(0.185)	(0.011)	(0.938)	(0.094)	(0.180)	(0.604)
Observations	1859	1264	1859	1859	1376	1859

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

The Multivariate Probit Model

The final econometric specification to be estimated controls for cross-equation correlations using a multivariate probit model (Table 3.16). Parameter estimates are generally smaller than in the household-level random effects specification, but patterns of significance among the covariates are similar. One notable exception is mother's education, which is significant in the household level random effects specification, but insignificant under the multivariate probit. Migrant remittances have negative effects on the probability that a child participates in farm work, which is not captured in the random effects specification.

Table 3.16: Multivariate Probit Estimates

	School	Farm Work	Family Business	Child Care
Boy Indicator	-0.039	1.089***	-0.286***	-0.406***
	(0.118)	(0.154)	(0.082)	(0.110)
Household Composition				
Biological child indicator	0.145	0.171	0.143	-0.0273
	(0.132)	(0.113)	(0.123)	(0.127)
Number of girls	0.043	-0.117***	0.015	0.262***
	(0.039)	(0.038)	(0.045)	(0.061)
Number of boys	0.015	-0.092**	-0.055	0.134***
	(0.035)	(0.040)	(0.040)	(0.049)
Number of adult men	-0.037	0.057	-0.042	-0.119**
	(0.042)	(0.044)	(0.042)	(0.051)
Number of adult women	0.018	0.158***	-0.002	-0.092*
	(0.060)	(0.052)	(0.061)	(0.048)
Household Assets and Unearned Income				
Livestock Value (FCFA)	0.022**	-0.006	-0.000	-0.020
	(0.011)	(0.010)	(0.009)	(0.013)
Herd Size (Number of Animals)	-0.003	0.005*	-0.001	0.002
	(0.005)	(0.003)	(0.003)	(0.004)
Agricultural Capital (FCFA)	0.005	0.006**	-0.005	0.009
	(0.004)	(0.003)	(0.007)	(0.006)
Household Durables (FCFA)	0.003	-0.012	0.001	0.009
	(0.004)	(0.011)	(0.002)	(0.007)
Migrant Remittances (FCFA)	-0.027*	-0.071***	0.017	-0.026
	(0.016)	(0.022)	(0.025)	(0.026)
Parental Education				
Any Mother's Education	0.395	-0.218	0.243	0.261
(1=Yes)	(0.284)	(0.288)	(0.266)	(0.275)
Any Father's Education	0.377**	-0.172	-0.320	0.072
(1=Yes)	(0.180)	(0.164)	(0.204)	(0.191)

Table 3.16 (Continued)

	School	Farm Work	Family Business	Child Care
Age of HH Head	-0.001	0.001	-0.002	0.005
	(0.002)	(0.003)	(0.003)	(0.003)
Age of HH Head's spouse	0.006	-0.011***	0.001	-0.003
	(0.004)	(0.003)	(0.004)	(0.004)
Community Characteristics				
Access to River	-0.118	-0.256	0.185	0.104
(1=Yes)	(0.169)	(0.196)	(0.238)	(0.194)
Roads				
within 1-10km	0.553***	0.354	0.240	0.561*
	(0.187)	(0.290)	(0.267)	(0.312)
within 11-20km	0.474**	0.199	0.208	0.537
	(0.225)	(0.283)	(0.368)	(0.336)
greater than 20km	0.878***	0.432	0.416	0.808**
	(0.255)	(0.351)	(0.358)	(0.349)
Commune Population				
less than 5000 people	0.653	-0.079	-0.402	-0.943**
	(0.474)	(0.387)	(0.559)	(0.470)
5-10,000 people	-0.192	-0.545*	0.789*	-0.497
	(0.302)	(0.285)	(0.436)	(0.377)
10-20,000 people	0.102	0.941***	-1.115***	-0.838***
	(0.279)	(0.243)	(0.340)	(0.275)
Villages per Commune				
fewer than 10	0.309	2.109***	-2.492***	-0.636
	(0.503)	(0.470)	(0.727)	(0.684)
11-20 villages	0.563*	1.412***	-1.852***	-0.467
	(0.324)	(0.356)	(0.497)	(0.458)
21-30 villages	0.167	0.488	-0.832**	0.440
	(0.292)	(0.307)	(0.421)	(0.361)
School Characteristics: Primary				
Primary School in Village	1.711***	-0.233	1.094**	0.086
	(0.470)	(0.297)	(0.448)	(0.390)
Primary School within 1-5km	1.029*	-0.066	0.835*	-0.096
	(0.548)	(0.338)	(0.437)	(0.402)
Primary School farther than 5km	-0.124	-0.217	1.112*	0.158
	(0.594)	(0.442)	(0.605)	(0.512)

Table 3.16 (Continued)

	School	Farm Work	Family Business	Child Care
Multiple Primary Schools	0.879***	-0.065	0.241	-0.302
(1=Yes)	(0.220)	(0.241)	(0.335)	(0.334)
Student-Teacher Ratio	-0.012**	0.001	-0.011**	-0.003
	(0.006)	(0.004)	(0.006)	(0.004)
Secondary School in Village	0.439***	-0.122	-0.420*	-0.004
	(0.165)	(0.169)	(0.253)	(0.203)
High School in Village	0.133	0.308	-0.0792	1.792***
	(0.297)	(0.418)	(0.618)	(0.609)
Constant	-2.243***	-1.702***	0.997	-1.907***
	(0.586)	(0.570)	(0.680)	(0.618)
Observations	1859	1859	1859	1859

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

The results of the shock estimates (Table 3.10) under the multivariate probit model are quite similar to the estimates from the household random effects model. The parameter estimates are lower, but the patterns of significance remain constant. Of particular interest is the change in the child's participation in the family business in response to large crop loss shocks. The parameter estimate is almost four times less under the multivariate probit specification. Tables 3.17 and 3.18 present the results for the asset-shock interactions. These results differ significantly from the household-level random effects specification. For the crop loss shocks, durables have a duplicitous role depending on the magnitude of the shock. Interactions with large crop loss shocks have significant and negative impacts on the child's selection into the family business. Durable-small crop loss shock interactions raise the probability that a child will work in the family business. Livestock values interacted with large crop shocks lower the probability a child is withdrawn from school, suggesting that assets that are more liquid may serve as an alternative to changes in children's time allocation in response to crop shocks. In response to adult sicknesses, durables lower the probability that children are withdrawn from school when men are sick and the probability children work in the family business when women are sick. When women are sick, higher levels of durables increase the probability a child is withdrawn from school and participates in farm work. Livestock values have opposite effects on the probability a child is withdrawn from school when adults are sick. When men are sick, increased livestock value increases the probability a child is withdrawn from school, reflecting the increased labor demand to care for animals. When women are sick, increased livestock value lowers the probability a child is withdrawn from school.

Table 3.17: Multivariate Probit Asset-Crop Loss Shock Interactions

Interactions	Withdrawn from School	Farm Work	Family Business	Child Care
Durables x	-0.084	-0.018	-0.540***	0.031
Large Crop Loss	(0.074)	(0.080)	(0.195)	(0.157)
Durables x	0.000	-0.025	0.284**	0.007
Small Crop Loss	(0.025)	(0.019)	(0.111)	(0.031)
Agricultural Capital x	0.677	-0.056	-2.096**	-0.326
Large Crop Loss	(0.554)	(0.675)	(1.041)	(1.159)
Agricultural Capital x	-0.832	0.270	0.527	-0.679
Small Crop Loss	(0.661)	(0.427)	(0.647)	(0.772)
Livestock Value x	-0.188***	-0.026	0.057	-0.204
Large Crop Loss	(0.070)	(0.052)	(0.061)	(0.141)
Livestock Value x	-0.093	0.001	0.025	0.019
Small Crop Loss	(0.067)	(0.038)	(0.038)	(0.041)
Observations	761	761	761	761

Table 3.17 (Continued)

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100 000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interaction results displayed. Absolute value of z statistics are in parentheses. * significant at 10%, ** significant at 5%; *** significant at 1%.

Table 3.18: Multivariate Probit Estimates: Asset-Illness Shock Interactions

Interactions	Withdrawn from School	Farm Work	Family Business	Child Care
Durables x	-0.728***	-0.084	-0.010	-0.090
Sick Male	(0.261)	(0.074)	(0.066)	(0.057)
Durables x	0.196**	0.104*	-0.187**	0.011
Sick Female	(0.099)	(0.062)	(0.081)	(0.047)
Durables x	0.166	0.073	0.149	0.077
Sick Child	(0.162)	(0.159)	(0.137)	(0.210)
Agricultural Capital X	-1.064	0.259	-1.798	-0.169
Sick Male	(1.217)	(0.652)	(1.101)	(0.135)
Agricultural Capital x	-0.816	-0.241	0.170	-0.157
Sick Female	(0.581)	(0.467)	(0.443)	(0.582)
Agricultural Capital x	1.475	-0.765	1.187	-2.200**
Sick Child	(1.132)	(0.894)	(1.067)	(1.002)
Livestock Value	0.148***	0.066	-0.001	0.062**
x Sick Male	(0.038)	(0.041)	(0.056)	(0.026)
Livestock Value	-0.136**	-0.102**	-0.013	-0.046
x Sick Female	(0.058)	(0.040)	(0.042)	(0.030)
Livestock Value	-0.164	0.060	0.005	-0.015
X Sick Child	(0.112)	(0.045)	(0.048)	(0.076)
Observations	761	761	761	761

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100 000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interaction results displayed. Absolute value of z statistics are in parentheses. * significant at 10%, ** significant at 5%; *** significant at 1%.

VII. Conclusions

Understanding the mechanisms by which children's time is allocated to school, home production, and market production is fundamental to the development of a broader economics of children and the competing opportunity costs of their time. Children conduct multiple domestic and market-oriented production activities for their households. These activities directly contribute to income generation or free other household members to conduct renumerative activities. Most children who work contribute to household income or to meeting subsistence needs without being employed in the worst forms of child labor. However, participation in work outside of the worst forms can have differential effects; either increasing children's human capital from increased work experience or limiting their total time in school or the quality of schooling due to work requirements. Our understanding of child participation in market and domestic activities and these welfare effects are relatively underdeveloped compared to adult labor supply.

The model of children's work and schooling that is developed in Section 2 of this chapter explains selection into different activities based on the shadow value of a child's time. In the econometric specifications, proxies for the myriad of factors that may alter the value of the child's shadow wage include household composition, labor market opportunities represented by demographic variables, and school quality characteristics. Household composition and asset values, specifically livestock values, influence selection into work and schooling. Despite low incidences of formal education in northern Mali, father's and mother's education have large, significant point estimates. Proximity to school influences selection into school under all of our econometric specifications.

The importance of shocks on child welfare cannot be underestimated. While substitution into and out of market and domestic work is relatively innocuous, save the impact of the additional hours, substitution out of schooling has relatively long-term welfare consequences for the production of human capital. Children, once withdrawn from school, may have difficulty returning even after a few months of absence. To recuperate the loss of schooling time, children may have to completely repeat grade levels. This "ratchet" effect, that is, the shock's role of completely halting the process of human capital accumulation, holds more serious welfare implications than moving into or out of work activities. From a policy perspective, constructing insurance schemes to protect households against shocks have implications not only for household consumption, but also for children's work and schooling. In addition, these results illustrate that when women fall ill, children are substitutes for their home and market production. Investing in women's health care may have the secondary benefits of lifting households out of long-term poverty because children's schooling would not be reduced as often by immediate household labor demands.

As documented in the literature by such papers as Beegle et al. (2006), assets play a substantial role in protecting children from the negative effects of shocks. This chapter provides additional support for this empirical finding with one important caveat: types of assets may differ in providing insurance against shocks. Not only does the type of shock matter (income or labor productivity shock), but whether the asset in question is complementary to or a substitute for child labor. These results show that increasing assets such as livestock may have differential effects on child labor and schooling, depending on type of shock and who it affects within the household. However, household durables do insure children against adult illness and to a lesser extent, production shocks. More research to understand the interactions between asset types and the impact of shocks on child labor and schooling can improve interventions targeted at households that live in risky environments in order to reduce poverty in the long term by keeping children in school.

CHAPTER 4: CHANGES IN CHILDREN'S TIME ALLOCATION IN RESPONSE TO PRODUCTION AND HEALTH SHOCKS

I. Introduction

Excluding the worst forms of child labor, the welfare implications of child labor depend on the amount of time that children participate in work relative to schooling and the types of work in which they are employed. Without detailed information on the hours of children's activities, the magnitudes of a shock or a development intervention are masked by the analysis of participation variables that are only partial components of the distribution of children's time. However, increased information about the distribution of children's time comes at the expense of precision because hours data are likely to suffer from measurement error.

This paper has three main contributions. The first contribution is the estimation of the substitution effects induced by production and health shocks on the child's time distribution (schooling, farm work, work in the family business, domestic chores, and child care). Several authors have explored the effects of production shocks on children's time include Jacoby and Skoufias (1997) in India, Jensen (2000) in Côte d'Ivorie, Beegle et al. (2006) in Tanzania and Guarcello et al. (2007) in Cambodia. However with the exception of Beegle et al. (2006), labor substitution effects are only investigated with respect to work and schooling categories, despite the fact that children engage in a multiplicity of domestic and market oriented work. Emerson and Souza (2003, 2006) provide evidence that working earlier in life is harmful to future adult earnings and that there is intergenerational persistence of child labor. If labor substitution effects from shocks are large, then social protection programs such as crop insurance or the development of improved health services will have implications for children apart from their direct effects.

Evaluations of the impact of several social protection programs on the distribution of children's time including pensions (Edmonds 2004), conditional cash transfers (de Janvry et al. 2006), and school feeding programs (Ravallion and Wodon 2000) illustrate the mixed impact that interventions may have on child labor. While Edmonds (2006) finds that pensions do increase children's school and decrease child labor, Ravallion and Wodon (2000) find that school feeding programs induce changes in the distribution of children's time, raising schooling, reducing leisure and only slightly lowering children's work time. The welfare effects of the school feeding program then become ambiguous because reduced leisure time may lower the quality of schooling. In the case of the PROGRESA conditional cash transfer program, de Janvry et al. (2006) find that school enrollment was protected for children whose household benefited from PROGRESA, but parents still increased child labor in the face of income shocks. Because different social protection programs have had ambiguous effects on the distribution of children's time, this research focuses on identifying how shocks induce labor substitution effects.

The paper's second contribution is to investigate the role that assets play in potentially mitigating the effects of increased hours in response to production and health shocks. Different types of assets (durables, agricultural capital, and livestock) may have differential effects with respect to production shocks and health shocks to men, women and other children within the household. These differential effects exist because variation in asset composition provides households different ex-post smoothing mechanisms which may include more or less child labor to effectuate the strategy.

Lastly, this paper tests an alternative measure to hours data for eliciting the distribution of children's time between work, school and leisure. Hours data are subject to higher propensities of measurement error than participation variables due to recall bias. Tradeoffs exist between the more detailed information provided by hours data and the quality of the estimates. In the United States, prominent surveys such as the Panel Survey of Income Dynamics and the Current Population Survey have been subjected to verification surveys to investigate the measurement error in hours data reported in these surveys. Duncan and Hill (1985), Mellow and Sider (1983), and Rodgers et al. (1993) all find evidence that measurement error is a significant source of bias in hours data estimates. In agricultural areas where households primarily engage in self-employed activities that do not have finite work schedules, measurement error is likely to be an important source of bias. Because children's hours data is normally reported by proxy respondents, measurement error may, in fact, be a more significant source of bias. It is important to note that, even though hours data is subject to measurement error critiques, bias in dependent variables increases the overall variance of estimates without biasing the parameter estimates per se (Deaton 1997). Bias in the dependent variable does decrease the likelihood of identifying significant effects of covariates.

In a subjective child labor module directed to child respondents aged 10 to 17, an alternative method of collecting information regarding the relative distribution of time was employed. Children were engaged in a game that measured the distribution of the child's time between work, school and leisure activities by having the child choose 10 cards among three different sets of colored cards to visually represent their week. This survey instrument is similar to the subjective evaluations of rainfall probability that Lybbert et al (2007) conducted in Ethiopia and Kenya with pastoralists. Comparisons between the hours data and these subjective welfare data yield a consistent story with respect to the descriptive patterns of child labor and the magnitudes of time spent in differing activities at the means. However, when compared to the estimated conditional labor supply and schooling coefficients, the impact of shocks on the subjective welfare variables mimic more closely the results from the participation variables.

The organization of this paper is standard. The second section presents the analytic framework for examining the effects of production and health shocks. This section builds on the model of child labor presented in Chapter 3. The third section describes the data, specifically with respect to the subjective child labor module. The fourth section presents the data's descriptive statistics. The fifth section outlines the econometric specifications used to identify the effects of shocks on child labor and schooling hours, while the sixth section presents the empirical results. The last section concludes.

II. Analytic Framework

In the previous dissertation chapter, an analytical framework for analyzing the factors influencing the labor allocation patterns of children among schooling, market production and domestic production was developed. Conditions A.7, A.8 and A.9 from the first order conditions in Chapter 3[31] include equations for schooling hours,

[31] Equations referenced are found in Chapter 3, under VIII: Model.

domestic work, and market oriented work. This model builds on Beckerian models of human capital investment in children within unitary household models (Becker 1965; Becker and Lewis 1973; and Becker and Tomes 1976), agricultural household models developed by Rosenzweig (1977a, 1977b, 1980), Singh et al. (1986), and de Janvry et al. (1991), and more recent models of child labor by Basu and Van (1998), Basu (1999), Baland and Robinson (2000), Cigno and Rosati (2005), and Edmonds (2007).

In deriving the reduced form labor and schooling supply functions, a Cobb-Douglas functional form was assumed for the work functions, but no functional form is assumed for the schooling function. The schooling hours are given by equation 4.1, domestic work supply function is given by equation 4.2, and the market work supply function is given by equation 4.3.

$$T_C{}^S = g\left[\frac{\lambda_1}{\beta n \frac{\partial U^*}{\partial y_3}\frac{\partial y_3}{\partial E}\theta f(Q,s)}\right]^{-1} \tag{4.1}$$

$$T_C{}^H = \left[\frac{w_C{}^H + \frac{\lambda_1}{\partial u / \partial a_2}}{(1-\alpha)(T_A{}^H)^\alpha}\right]^\alpha \tag{4.2}$$

$$T_C{}^F = \left[\frac{w_C{}^F + \frac{\lambda_1}{\partial u / \partial a_1}}{p\delta(1-\alpha)(T_A{}^F)^\alpha}\right]^\alpha \tag{4.3}$$

Variables that are positively associated with children’s market and domestic work are those that affect the return on children’s time in the market or domestic activity and the opportunity cost of the child's time. Variables that are inversely related to children's work time include the allocation of adult's time in the market or domestic tasks. Adult labor supply is proxied by the labor availability of adults given by the household's composition.

Children's time allocation is determined by seven sets of observable characteristics (child, adult, household, village, and district characteristics; exposure to shocks and shock-asset interactions) and a household level unobservable (household preferences) summarized in the equations to be estimated below (Equations 4.4-4.6). Child characteristics include the child's age, ethnicity and gender. Adult characteristics include parental ages and education. Durables, livestock values and number of animals, value of agricultural capital, and unearned migrant remittances are the variables employed to characterize the household's assets. Household composition (the number of adult men, women, girls and boys) are also included as household variables that proxy for total available household labor. Village level variables include such indicators as whether the village is urban or rural, access to roads, school proximity, and school quality capture access to services and infrastructure. District level variables proxy for labor market integration which include village population indicators and the density of villages in the district. Seasonal indicator variables are also included in the specification to control for potential variation in the labor demand between periods. A regional indicator is also included to distinguish the five regions in the survey. The reduced form equations are summarized by equations 4.4 to 4.6 below.

$$T_C^S = T^S(Child, Adult, Household, Village, District, Shocks, Shock\ x\ Asset, HHpreferences) \tag{4.4}$$

$$T_C^H = T^H(Child, Adult, Household, Village, District, Shocks, Shock\ x\ Asset, HHpreferences) \quad (4.5)$$

$$T_C^F = T^F(Child, Adult, Household, Village, District, Shocks, Shock\ x\ Asset, HHpreferences) \quad (4.6)$$

III. Data Description

The data for this paper was collected as part of the *Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006* which is described fully in Chapter 2 of the dissertation. Of particular interest for this paper is the comparison of the effect of using hours data versus a subjective survey module posed to children directly to estimate the effect of household composition, assets, community characteristics and shocks on the distribution of children's time.

This paper analyzes information about children's hours in different activities (schooling, domestic work and market work) from the children's questionnaire and the relative distribution of children's time from a subjective child labor module within the children's questionnaire. Children's hours data are potentially biased with recall errors and proxy respondent biases. In a series of papers that investigate measurement error in the reporting of hours worked by adults, Mellow and Sider (1983), Duncan and Hill (1985) and Rodgers et al. (1993) all find evidence of significant measurement error in reported hours worked. It is unclear in the case of children in Northern Mali whether perceptions of time which are seasonally linked with the agricultural seasons and daily linked with the Muslim prayer cycle would provide more precise estimates than hours measured with watches or clocks. If households over-report hours of children's work relative to the true value, parameter estimates will not be biased, but the overall variance of the equation increases, decreasing the precision of the parameters. Reported hours data for children's activities as well as subjective evaluations of children's work over the previous week are investigated to evaluate whether differences in survey design will produce different patterns of significance in the covariates.

During the subjective module, children are given three stacks of ten different colored pieces of paper[32]. The game was explained during community meetings and individually with each survey respondent, so that sufficient time and reflection passes before respondents play the game. Respondents are asked to pick ten total pieces of paper in whatever color combinations they choose to represent their allocation of time between work, school and leisure. Each piece of colored paper represents work, school or leisure time. The exact question in English is the following:

> *Now, I'd like to do an exercise with you to understand the amount of time you spend in school, work and leisure. Here are three different colored papers. The red papers are representative of time in school. The yellow papers are representative of time doing work to help the family earn money. For example, time when you fish, follow the animals, or work with the family business. The blue papers are representative of leisure time. Now, I would like that you to choose 10 papers of any of the colors that represent your typical day. For example, if you work more than you have leisure time, it is necessary to choose more of the yellow papers than blue papers. If you go to work more than school, it is necessary to choose more of the yellow papers than the red papers. If you have more leisure time than time in school, it is necessary to choose more of the blue papers that the red papers. Do you understand? (If so, give the child the three types of the papers. If not, explain again.)*

[32] Lybbert et al. (2007) use a similar approach to derive the subjective probability distribution of pastoralist's climate forecasts in Southern Ethiopia and Northern Kenya.

Using this module generates an approximate distribution of children's time between the three categories. If simple recall of hours spent in each activity, children might be prone to recall errors regarding the distribution of hours spent across the three areas. In this way, the feature of prime interest, the distribution of time spent across work, school and leisure is placed at the forefront of the exercise. If hours are simply recalled for the activities and then the distribution is calculated, the implicit purpose of the survey question is masked from the respondents.

Borgers et al. (2000) suggest that with 11-16 year olds an important feature of obtaining reliable survey responses is to keep survey respondents motivated. A face to face interview with visual aids can serve to keep the attention of youth, so long as a proper interview environment with out perceived pressure from parents is possible. The questionnaire design also gives children the opportunity to "practice" responses to this type of question by preceding the question of interest, their allocation of time between school, work and leisure, with questions about the relative distribution of their diets between rice, sorghum and millet in the first question and cereals, fruits and vegetables, and meat in the second question. Evidence regarding the reliability of this type of question is presented in the following section.

IV: Descriptive Statistics

To examine changes in the distribution of children's time across work, schooling and leisure, hours data and the results of the subjective child labor module that elicits the relative distribution of children's time across the three activities are presented. Table

4.1 presents the hours and subjective module data[33]. According to the hours data presented in Table 4.1, children spend 38.9 hours per week working. 20.2 hours per week, or 51.9% of children's work time, is allocated to domestic work and 18.69 hours per week, or 48.1% is devoted to market oriented work. Work constitutes 34.7% of children's time, 44.6% of children's time is devoted to leisure, and 9.9% of the child's time is devoted to school (approximately 11 hours per week) [34]. When compared to the subjective child labor module, the allocation of children's time working is reported to be 47.6%[35]. However, children's leisure time is reported to be 29.4% and time at school or doing school work is 23%.

Table 4.1: Children's Time Allocation: Unconditional Hours by Activity

Hours	Mean	Std. Dev.
School	11.06	0.51
Farm	9.50	0.45
Family Business	9.18	0.38
Chores	15.48	0.50
Child Care	4.72	0.28
Market Work	18.69	0.64
Domestic Work	20.20	0.65
Total Work	38.89	1.06
Subjective Measures		
School	2.30	0.10
Work	4.76	0.08

Note: Probability weighted means. N=1675

---

[33] Due to data cleaning to eliminate outliers, 245 observations were trimmed from the sample due to unrealistic hours reports over 18 hours a day in domestic or market activities which represents 10% of the sample.

[34] The percentage of children's time devoted to particular activities in this paragraph is calculated from the hours data assuming that the child sleeps 8 hours a day and that this time is not included as leisure time. The reason for this is that sleeping time was not included as leisure time in the subjective module. Since the reason we are presenting the hours data is to make some comparison to the subjective results, the methodology to calculate comparable statistics ought to be based on the same fundamental assumptions.

[35] The percentage of children's time allocated to schooling, work, or leisure can be calculated from their mean responses by simply multiplying the response by 10 because the child selects 10 differently colored cards to represent their week. Hence, each card represents a decile of time.

Figures 4.1, 4.2, and 4.3 illustrate the distribution of the responses, work, school and leisure for the subjective module. The work responses form a bimodal distribution with a lower peak centered around 2 and a higher peak centered around 7 (Figure 4.1). Perhaps more predictably, the schooling responses also have a bimodal distribution around 0 and 6 which suggests that children either go to school a lot, almost 60% of their time or not at all (Figure 4.2). Leisure has a unimodal distribution centered at 2 (Figure 4.3).

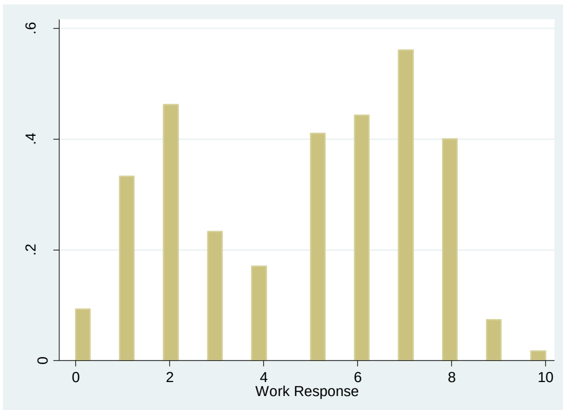


Figure 4.1: Histograms of Children's Work Rankings

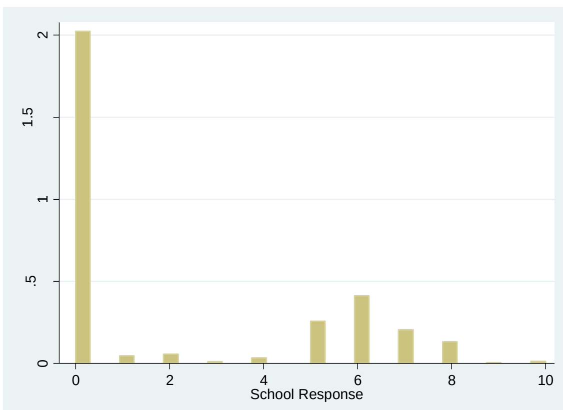
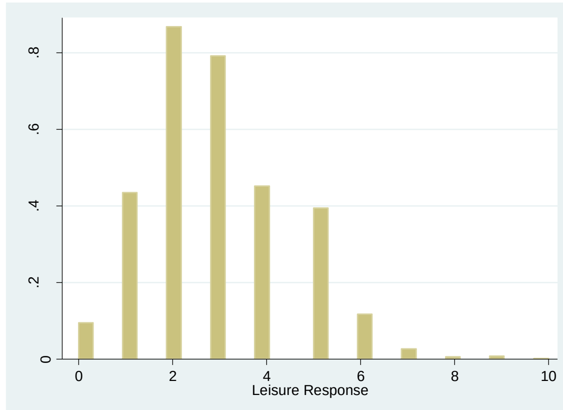


Figure 4.2: Histograms of Children's School Rankings



Figures 4.3: Histogram of Children's Leisure Rankings

The correlation among the same colored response groups for the work, school and leisure questions and the two "practice" questions described in the Data Description permit an internal verification of independent response patterns. If previous same colored responses yield correlated responses in later questions, the independence of a respondent's responses would be questionable. Given the respondents are aged 10-17, a skeptic might assert a "favorite color" hypothesis to explain response patterns. However, correlations are low between same colored questions (Table 4.2). The highest correlations presented in Table 4.2 exist between yellow responses between sorghum and legume consumptions (.15). The largest positive correlations between similar colored response categories and the work, school and leisure categories of interest are leisure and millet consumption with a .1 correlation. Other correlations between the response categories of interest and the other similarly colored responses are negative.

Table 4.2: Correlations between Color Groups in Questions

	Red Responses		
	Q1-Rice	Q2-Cereal	Q3-School
Q1-Rice	1		
Q2-Cereals	0.122	1	
Q3-School	0.0305	-0.1068	1
	Yellow Responses		
	Q1-Sorghum	Q2-Legumes	Q3-Work
Q1-Sorghum	1		
Q2-Legumes	0.1502	1	
Q3-Work	-0.0153	-0.1295	1
	Blue Responses		
	Q1-Millet	Q2-Meat	Q3-Leisure
Q1-Millet	1		
Q2-Meat	0.0285	1	
Q3-Leisure	0.0977	-0.0446	1

Hours data by rural/urban and gender dimensions are disaggregated in Table 4.3. Urban children (14.7 hours) report four additional hours of schooling than rural children (10.5 hours) per week. However, the unconditional schooling hours mean is no different between girls and boys. Boys report more intensive farm activity (13.25 hours) versus girls (4.66 hours). Girls report higher numbers of hours in the family businesses that are generally female run, doing domestic chores, and providing child care for other children. Rural children do more market oriented work, while urban children do more domestic work. Farm work and work in the family business mean hours are greater in the rural context by 4.6 hours and 1 hour, respectively. Domestic chores and providing child care are 2.6 hours and 2.4 hours greater in urban areas, respectively. Disaggregated hours data by the child's age are presented in Table 4.4. Mean unconditional weekly hours reveal that younger children (ages 10-13) spend more time than older children (ages 14-17) watching siblings and going to school. Children do larger amounts of domestic chores and work in the family business as they grow older. Weekly hours of farm work increases slightly as children become older as well.

Table 4.3: Children's Time Allocation: Unconditional Hours per Week of Girls and Boys in Rural and Urban Areas

	Urban		Rural		Girls		Boys	
Hours	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
School	14.72	0.92	10.54	0.57	11.05	0.80	11.07	0.67
Farm	6.32	0.70	9.95	0.50	4.66	0.56	13.25	0.63
Family Business	8.35	0.67	9.30	0.42	11.33	0.62	7.52	0.45
Chores	17.75	1.03	15.16	0.55	20.55	0.82	11.56	0.56
Child Care	6.88	0.47	4.41	0.31	6.28	0.49	3.51	0.30
N	501		1174		733		942	

Table 4.4: Children's Time Allocation: Unconditional Hours per Week by Child's Age

Age	N		School	Farm	Family Business	Chores	Child Care
10	281	Mean	12.45	7.75	8.31	12.59	4.86
		SD	1.22	0.90	0.80	0.98	0.62
11	140	Mean	12.83	6.43	9.47	15.81	6.31
		SD	1.89	0.97	1.45	2.18	1.14
12	246	Mean	12.60	10.18	9.75	16.26	4.44
		SD	1.48	1.21	1.13	1.42	0.61
13	178	Mean	10.08	9.35	10.53	16.11	7.09
		SD	1.47	1.33	1.06	1.55	1.08
14	231	Mean	14.14	7.91	6.68	13.26	2.39
		SD	1.32	0.91	0.77	1.12	0.44
15	212	Mean	7.75	13.53	9.87	15.31	4.96
		SD	1.23	1.51	1.06	1.38	0.72
16	250	Mean	8.20	10.49	9.69	18.44	5.10
		SD	1.19	1.49	1.01	1.32	0.90
17	137	Mean	9.74	9.95	10.86	18.73	3.99
		SD	1.94	1.45	1.51	1.95	0.84

Descriptive statistics for the covariates are displayed in Tables 4.5.A, 4.5.B, 4.6, and 4.7. These covariates include children's characteristics (sex, age, and ethnicity), parental characteristics (parent's age and education), household composition variables, household assets and unearned income (livestock numbers and value, agricultural capital, durables and migrant remittances), and production and health shocks (Tables 4.5.A and 4.5.B). Table 4.6 presents village characteristics including regional dummies, village access to roads, commune population, and villages per commune which all proxy for labor market integration and economic opportunities for adults and children. Table 4.7 displays the school characteristics which account for school availability and quality available to children. The distribution of shocks across regions is presented in Table 4.8 which are discussed in the previous chapter.

Table 4.5.A: Descriptive Statistics:
Household and Child Characteristics

	Mean	Std. Dev.
Child Characteristics		
Sex (Boy=1)	0.545	0.498
Ethnicity		
Sonrai	0.665	0.472
Tamasheq	0.134	0.341
Peuhl	0.111	0.313
Bambara	0.040	0.196
Other Ethnicity	0.050	0.217
Age Dummies		
Age 10	0.201	0.401
Age 11	0.075	0.264
Age 12	0.138	0.345
Age 13	0.085	0.279
Age 14	0.135	0.342
Age 15	0.129	0.335
Age 16	0.145	0.353
Age 17	0.091	0.287

Table 4.5.A (Continued)

	Mean	Std. Dev.
Adult Characteristics		
Mother's Education (1 if any education)	0.055	0.227
Father's Education (1 if any education)	0.106	0.308
Age of Household Head	41.2	21.6
Age of Household Head's spouse	33.7	14.7

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1,856.

Table 4.5.B: Descriptive Statistics: Household and Child Characteristics

	Mean	Std. Dev.
Household Composition		
Own Child	0.803	0.398
Number of Girls in HH	1.407	1.215
Number of Boys in HH	1.722	1.361
Number of Adult Women in HH	1.697	1.277
Number of Adult Men in HH	1.638	1.148
Household Assets and Unearned Income		
Herd Size	19.18	19.54
Herd Value (FCFA)	531946	57044
Agricultural Capital (FCFA)	47051	12744
Durables (FCFA)	302671	69356
Migrant Remittances (FCFA)	40508	114356
Shocks		
Production Shock		
No Crop Loss	0.533	0.042
Small Crop Loss	0.217	0.034
Large Crop Loss	0.250	0.036
Labor Availability Shock		
Adult Male Sick	0.131	0.019
Adult Female Sick	0.212	0.045
Child Sick	0.144	0.037

Notes: All variables are population weighted means and the standard errors are corrected for clustering. For all variables, N=1,856.

Table 4.6: Descriptive Statistics:
Community Characteristics

Variable	Mean	Std. Dev.
Regional Characteristics and Distribution		
Urban	0.086	0.281
River Access	0.331	0.472
Regional Indicators		
Niafunke	0.377	0.486
Goundam	0.166	0.373
Dire	0.159	0.367
Tombouctou	0.099	0.300
Rharous	0.073	0.261
Bourem	0.119	0.325
Kidal	0.007	0.081
Access to Roads		
Road Connects with Village	0.139	0.347
within 1-10km	0.417	0.495
within 11-20km	0.232	0.423
more than 20km	0.212	0.410
Commune Population		
less than 5000	0.093	0.291
5001-10000	0.225	0.419
10001-20000	0.391	0.490
20001-30000	0.146	0.354
more than 30000	0.146	0.354
Villages per Commune		
Less than 10	0.152	0.361
11-20	0.205	0.405
21-30	0.285	0.453
more than 30	0.358	0.481

N=151 villages

Table 4.7: School Characteristics

Primary School Characteristics			
Variable	Obs.	Mean	Std. Dev.
No Primary School Access	151	0.258	0.439
Primary School in Village	151	0.563	0.498
less than 5 km	151	0.099	0.300
greater than 5 km	151	0.079	0.271
Multiple Primary Schools in Village	151	0.132	0.395
Student-Teacher Ratio—Primary	107	45.496	20.418
Repetition Rate—Primary	98	0.305	0.148
Boys Exam Pass Rate—Primary	71	0.651	0.266
Girls Exam Pass Rate—Primary	67	0.590	0.325
Secondary School Characteristics			
Secondary School in Village	151	0.159	0.367
High School Characteristics			
High School in Village	151	0.026	0.161

Table 4.8: Distribution of Shocks by Region

Region	Male Illness	Female Illness	Child Illness	Small Crop Shocks	Large Crop Shocks
Niafunke	0.107	0.082	0.082	0.138	0.198
Goundam	0.079	0.041	0.011	0.185	0.166
Dire	0.183	0.165	0.018	0.064	0.009
Tombouctou	0.270	0.255	0.102	0.153	0.163
Rharous	0.329	0.146	0.195	0.000	0.890
Bourem	0.071	0.503	0.420	0.330	0.260

V: Econometric Specification

To investigate the household's allocation of children's time in domestic work, market work and school, three econometric specifications using children's hours of work in the past week and the child's own subjective evaluation of their distribution of time are described below. The first specification investigates conditional hours in work and schooling activities controlling for potentially confounded household unobservables, such as parental preferences over the allocation of children's time, with a random effects specification. The marginal effect on labor and schooling hours in response to production and health shocks are identified using a second specification. The effects of asset-shock interactions investigates the role that assets may have in mitigating increases in children's work in response to unexpected shocks. The last specification, an ordered probit with random effects, uses responses from the child's subjective evaluation of the distribution of their time to compare the effects of covariates with the hours specifications, the impact of shocks and asset-shock interactions using an ordered probit model.

Specification 1: Measuring Conditional Labor Supply Functions: Controlling for Unobservables

The marginal effects of child-specific (age, gender), parental (age, education), household (assets, unearned income, household composition), village (size, school and road infrastructure), district (population and density), and region dummies on conditional child labor supply functions and schooling hours are estimated which control for potential household unobservables. Conditional labor supply and schooling hours specifications are examined because the allocation of children to domestic work, market work or schooling is a two step decision, participation and conditional hours response as described in Heckman's seminal work (Heckman 1974 and 1990). In Chapter 3 of the dissertation, participation decisions by households were analyzed to investigate the influence of specific covariates and shocks. However, outside of the worst forms of child labor, negative impacts on child welfare or their longer term human capital are difficult to decipher if the focus is solely on participation. Attention is now turned to the conditional hours specification which is specified:

$$Hours_{aih} = \beta X_{ih} + \gamma Z_h + \varepsilon_{ih} \quad , \tag{4.7}$$

where $\varepsilon_{ih} = c_h + v_{ih}$, X_{ih} are child and parental characteristics and Z_h are village, district and region variables associated with the household.

Household unobservables, c_h, including parental preferences, are likely influences over the allocation of children's time. Since fixed effects capture all time-invariant characteristics of the cross-sectional units, no estimate of the effect of parental education or household assets on child work and school participation would be possible. However, these effects have a documented impact on children's schooling and work (Dumas and Lambert 2004), which cannot be ignored. To control for potential household unobservables, additional assumptions with respect to the strict exogeneity of the covariates on children's hours are required and the uncorrelatedness of the household unobservable c_h and child and household characteristics, X_{ih} and Z_h.

Specification 2: Identifying Labor Substitution Effects of Production and Health Shocks and Asset-Shock Interactions

To investigate the role that shocks may have on children's work and school hours, the dichotomous shock variable is included in the above specification which becomes:

$$Hours_{aih} = \beta X_{ih} + \gamma Z_h + \phi shocks_h + \varepsilon_{ih} \quad . \tag{4.8}$$

If $\phi > 0$, the shock increases the number of hours allocated to work or schooling. The role of assets in mitigating the impact of shocks on children's hours can also be investigated as in Beegle et al. (2006). Including an asset shock interaction yields an estimate of the responsiveness of assets, given a shock, on the children's hours in work or school such that:

$$Hours_{aih} = \beta X_{ih} + \gamma Z_h + \phi shocks_h + \alpha(assets_h \cdot shocks_h) + \varepsilon_{ih} \ . \tag{4.9}$$

When $\alpha > 0$, increased assets also increase the hours of work or schooling. With respect to work, this suggests that assets are child labor complementary. However, with respect to schooling, it suggests that assets are complementary to children's school hours. When $\alpha < 0$, assets mitigate the effects of unexpected production and illness shocks on children's work. As noted in the previous chapter, cross-sectional variation of asset and shock interactions are not ideal specifications to identify the ex-post smoothing role that assets may have in mitigating child labor responses to shocks due to variation within the sample of the timing of asset liquidation. This potentially confounds a wealth effect with the asset liquidation effect as a household response to the shock. However, the inclusion of seasonal variables controls for potential variations in the interaction terms due to the season of the household's responses.

Specification 3: Measuring Intensity of Schooling and Work Activities using Children's Subjective Responses: Ordered Probit model with Random Effects

An ordered probit model with random effects is used to estimate the impact of covariates on the intensity of child work as measured by the subjective child labor module that elicits the distribution of children's work time relative to other activities.

The dependent variable will be the rank that the child puts on the amount of time they spend conducting work for the household or schooling.

Let $e \mid x, z \sim Normal(0,1)$. From the subjective child labor module, the threshold parameters are divided into one unit increments such that:

$$
\begin{aligned}
&y=0 && \text{if } y^* \le 1\\
&y=1 && \text{if } 1 < y^* \le 2\\
&y=2 && \text{if } 2 < y^* \le 3\\
&y=3 && \text{if } 3 < y^* \le 4\\
&y=4 && \text{if } 4 < y^* \le 5\\
&y=5 && \text{if } 5 < y^* \le 6\\
&y=6 && \text{if } 6 < y^* \le 7\\
&y=7 && \text{if } 7 < y^* \le 8\\
&y=8 && \text{if } 8 < y^* \le 9\\
&y=9 && \text{if } 9 < y^* \le 10\\
&y=10 && \text{if } y^* > 10.
\end{aligned}
\tag{4.10}
$$

Each response probability can be calculated from the conditional distribution of y given x using the standard normal assumption for the error term[36].

$$
\begin{aligned}
&P(y=0 \mid X,Z,c)=P(y^* \le \alpha_1 \mid X,Z,c) = P(\beta X + \gamma Z + c + \varepsilon \le \alpha_1 \mid X,Z) = \Phi(\alpha_1 - [\beta X + \gamma Z])\\
&P(y=1 \mid X,Z,c)=P(\alpha_1 \le y^* \le \alpha_2 \mid X,Z,c) = \Phi(\alpha_2 - [\beta X + \gamma Z]) - \Phi(\alpha_1 - [\beta X + \gamma Z])\\
&.\\
&.\\
&P(y=9 \mid X,Z,c)=P(\alpha_9 \le y^* \le \alpha_{10} \mid X,Z,c) = \Phi(\alpha_{10} - [\beta X + \gamma Z]) - \Phi(\alpha_9 - [\beta X + \gamma Z])\\
&P(y=10 \mid X,Z,c)=P(y^* > \alpha_{11} \mid X,Z,c) = 1 - \Phi(\alpha_{11} - [\beta X + \gamma Z])
\end{aligned}
\tag{4.11}
$$

[36] Subscripts are suppressed for notational convenience.

The log likelihood function that is maximized is formulated:

$$l_i(\alpha,\beta,\gamma) = [y_i = 0]\log(\Phi(\alpha_1 - [\beta X + \gamma Z]) + [y_i = 1]\log(\Phi(\alpha_2 - [\beta X + \gamma Z]) \\ - \Phi(\alpha_1 - [\beta X + \gamma Z]) + ... + [y_i = 10]\log(\Phi(\alpha_{11} - [\beta X + \gamma Z]) \quad (4.12)$$

The results from these three specifications are discussed in the next section.

VI: Empirical Results

Hours Data Results

Ordinary least squares regression results are presented in Table 4.9 which serve as a comparison to the preferred specification which controls for household level unobservables. In Table 4.10, the household level random effects estimates are presented. Household variables, including child and parental characteristics, have significant effects on children's hours of work and school. Gender, in particular, has significant effects on the allocation of children's time. At the mean, boys spend 5 hours more doing farm work, but less time than girls in the family business (-3.2 hours), doing domestic work (-6 hours), and providing childcare (-2.9 hours). Mother's and father's education lowers the amount of time children spend doing domestic work by 5.2 hours and 3.8 hours, respectively. However, education has no effect on market oriented work or schooling hours. Household composition, measured by the numbers of girls, boys, men and women in the household, also have significant effects on certain domestic and market activities. Additional girls or boys increases the amount of time children spend conducting childcare, while additional girls also increase the time a child conducts household domestic work. Household assets have no significant effects on children's hours in work and school. A plausible hypothesis for this result would be that assets influence selection into certain activities, but once a child is selected into an activity, they work a given amount. This hypothesis is supported by evidence in Chapter 3.

Table 4.9: Conditional Schooling and Labor Supply Functions

	School	Farm	Family Business	Chores	Childcare
Boy Indicator	-0.425	6.499***	-3.841***	-5.931***	-2.434***
	(0.522)	(1.615)	(1.212)	(1.274)	(0.774)
Household Composition					
biological child indicator	-1.243	0.682	0.683	-2.153	-1.862*
	(1.166)	(1.367)	(1.226)	(1.372)	(1.041)
number of girls	-0.418	0.413	0.081	0.881**	0.756***
	(0.361)	(0.687)	(0.353)	(0.442)	(0.257)
number of boys	-0.114	-0.503	-0.285	-0.536	0.0745
	(0.255)	(0.565)	(0.381)	(0.468)	(0.393)
number of Adult Men	-0.357	0.667	0.084	0.733	-0.634
	(0.332)	(0.671)	(0.391)	(0.498)	(0.390)
number of Adult Women	-0.363	-0.090	-0.846	-0.794	-0.79
	(0.316)	(0.745)	(0.668)	(0.650)	(0.509)
Father's Age	0.016	-0.048	0.013	0.008	0.056***
	(0.017)	(0.041)	(0.025)	(0.025)	(0.021)
Mother's Age	-0.009	0.004	0.062*	-0.050	0.019
	(0.031)	(0.059)	(0.033)	(0.049)	(0.025)
Household Assets					
Livestock Value (FCFA)	0.047	0.039	-0.106	-0.124	0.098
	(0.033)	(0.177)	(0.103)	(0.099)	(0.070)
Herd Size (Number of Animals)	-0.040*	-0.009	0.018	0.032	-0.018
	(0.021)	(0.049)	(0.034)	(0.032)	(0.021)
Agricultural Capital (FCFA)	-0.041**	-0.026	0.029	-0.052***	0.015
	(0.020)	(0.037)	(0.022)	(0.017)	(0.017)

Table 4.9 (Continued)

	School	Farm	Family Business	Chores	Childcare
Household Durables (FCFA)	0.059	-0.447*	-0.086*	0.015	-0.073
	(0.039)	(0.235)	(0.050)	(0.082)	(0.047)
Migrant Remittances (FCFA)	-0.151	0.058	0.381***	0.324	0.326**
	(0.124)	(0.288)	(0.099)	(0.227)	(0.146)
Parental Education					
Any Mother's Education (1=Yes)	-0.913	-0.872	-1.658	-6.507**	-1.56
	(1.113)	(3.130)	(2.114)	(2.780)	(1.025)
Any Father's Education (1=Yes)	0.367	3.477*	-1.307	-3.095*	-0.637
	(0.744)	(2.096)	(1.615)	(1.611)	(1.407)
Community Characteristics					
Access to River (1=Yes)	-5.775**	6.739**	4.519***	5.484***	1.742
	(2.839)	(2.636)	(1.691)	(1.852)	(1.422)
Roads					
within 1-10km	-3.017	-6.837**	-2.058	-8.836***	-1.926
	(2.497)	(3.313)	(2.095)	(2.809)	(1.793)
within 11-20km	0.539	-2.015	-0.258	-6.510**	2.217
	(3.215)	(3.761)	(2.740)	(3.087)	(1.820)
greater than 20km	0.100	-5.471	0.017	-8.253***	-4.623**
	(2.593)	(3.617)	(2.780)	(2.917)	(2.215)
Commune Population					
less than 5000 people	-1.695	-1.317	6.193*	1.908	-7.228*
	(2.879)	(4.813)	(3.575)	(3.423)	(4.156)
5-10,000 people	-0.839	0.792	3.755	12.830***	2.741
	(4.624)	(3.869)	(2.873)	(3.004)	(2.179)
10-20,000 people	-2.132	-1.786	-2.572	-0.989	-5.297***
	(2.556)	(2.385)	(1.589)	(2.006)	(1.898)
Villages per Commune					
fewer than 10	2.310	-2.615	-6.960	-19.850***	-6.238
	(5.806)	(6.788)	(5.444)	(4.538)	(4.163)
11-20	0.071	-3.871	-6.876**	-15.74***	-10.96***
	(4.059)	(5.474)	(3.333)	(3.616)	(2.661)

Table 4.9 (Continued)

Villages per Commune	School	Farm	Family Business	Chores	Childcare
21-30	1.189	-1.779	1.407	-11.64***	-0.203
	(4.100)	(4.363)	(2.774)	(3.067)	(2.431)
School Characteristics					
Primary School in Village	-1.421	-3.218	-0.062	-3.028	-0.665
	(3.926)	(3.771)	(2.319)	(2.976)	(3.070)
Primary School within 1-5km	16.69	0.033	-0.597	-0.411	-4.096
	(12.440)	(4.599)	(3.045)	(3.949)	(2.989)
Primary School farther than 5km	-1.399	-2.681	-3.843	0.32	9.271
	(4.297)	(5.590)	(4.319)	(3.972)	(7.649)
Multiple Primary Schools	-1.521	-5.190**	-6.529***	-4.942*	-2.246
(1=Yes)	(1.790)	(2.388)	(2.111)	(2.742)	(2.461)
Student-Teacher Ratio	-0.006	0.078*	-0.006	0.071	-0.023
	(0.054)	(0.046)	(0.031)	(0.043)	(0.028)
Repetition Rate	5.445	-4.233	3.42	-4.019	-0.477
	(4.483)	(5.669)	(4.449)	(4.968)	(4.079)
Exam Pass Rate-Boys	9.99	7.386**	-2.862	-0.843	-6.486***
	(7.977)	(3.213)	(2.260)	(2.666)	(2.396)
Exam Pass Rate-Girls	-7.979	-7.171**	2.191	4.743*	7.134***
	(7.749)	(3.109)	(2.634)	(2.698)	(2.379)
Secondary School in Village	-0.633	-2.563	-0.671	-2.179	-3.770**
	(1.723)	(2.111)	(1.946)	(2.086)	(1.620)
High School in Village	-3.205	-5.905	9.986***	-2.309	0.277
	(2.792)	(4.958)	(3.060)	(3.107)	(2.360)
Constant	42.64***	11.16	11.84**	36.75***	22.24***
	(6.689)	(7.681)	(4.573)	(5.950)	(4.910)
Observations	582	802	1063	1399	728

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4.10: Conditional Schooling and Labor Supply Functions with Random Effects

	School	Farm	Family Business	Chores	Childcare
Boy Indicator	0.232	5.118***	-3.119***	-5.954***	-2.917***
	(0.300)	(0.860)	(0.582)	(0.727)	(0.502)
Household Composition					
biological child indicator	-0.343	-0.434	-0.389	-0.804	-0.762
	(0.566)	(1.089)	(0.831)	(0.977)	(0.683)
number of girls	-0.475	0.009	0.438	0.816**	0.545**
	(0.348)	(0.463)	(0.342)	(0.383)	(0.277)
number of boys	-0.155	0.256	0.042	-0.149	0.509*
	(0.312)	(0.408)	(0.311)	(0.340)	(0.278)
number of Adult Men	-0.239	0.997**	0.362	0.428	-0.331
	(0.412)	(0.486)	(0.388)	(0.450)	(0.372)
number of Adult Women	-0.454	-0.810	-1.231***	-1.011**	-0.443
	(0.426)	(0.522)	(0.424)	(0.491)	(0.405)
Father's Age	0.001	-0.059*	0.000	0.021	0.009
	(0.020)	(0.031)	(0.021)	(0.023)	(0.019)
Mother's Age	-0.003	0.033	0.038	-0.013	0.032
	(0.030)	(0.041)	(0.031)	(0.033)	(0.026)
Household Assets					
Livestock Value (FCFA)	0.050	-0.027	-0.097	-0.039	0.028
	(0.068)	(0.148)	(0.084)	(0.086)	(0.086)
Herd Size (Number of Animals)	-0.030	0.002	0.037	0.025	-0.006
	(0.030)	(0.045)	(0.031)	(0.034)	(0.029)
Agricultural Capital (FCFA)	-0.050	-0.073	0.038	-0.063	0.019
	(0.040)	(0.064)	(0.053)	(0.061)	(0.037)
Household Durables (FCFA)	0.060	-0.12	-0.090	-0.027	-0.052
	(0.052)	(0.173)	(0.073)	(0.065)	(0.059)
Migrant Remittances (FCFA)	-0.135	0.170	0.424*	0.316	0.215
	(0.149)	(0.289)	(0.221)	(0.215)	(0.206)

Table 4.10 (Continued)

	School	Farm	Family Business	Chores	Childcare
Parental Education					
Any Mother's Education	-1.068	0.259	-0.436	-5.167***	-0.828
(1=Yes)	(1.299)	(2.668)	(1.626)	(1.847)	(1.236)
Any Father's Education	-0.075	1.741	-2.051	-3.778***	-1.004
(1=Yes)	(1.083)	(1.955)	(1.336)	(1.408)	(1.094)
Community Characteristics					
Access to River	-3.499**	5.358***	2.595*	4.405***	2.022*
(1=Yes)	(1.519)	(1.962)	(1.348)	(1.496)	(1.197)
Roads					
within 1-10km	-0.15	-3.913**	-2.122	-5.640***	-2.024
	(1.972)	(1.905)	(1.530)	(1.605)	(1.433)
within 11-20km	2.029	0.15	-0.573	-3.527*	0.416
	(2.605)	(2.220)	(1.955)	(1.970)	(1.682)
greater than 20km	2.986	-3.57	-1.067	-5.542**	-2.957*
	(2.185)	(2.642)	(2.196)	(2.209)	(1.766)
Commune Population					
less than 5000 people	-0.509	-3.747	6.071	0.59	-9.354***
	(3.333)	(4.900)	(4.262)	(3.822)	(3.452)
5-10,000 people	2.958	-1.074	2.187	10.88***	-5.012***
	(2.454)	(3.323)	(1.943)	(2.311)	(1.771)
10-20,000 people	-1.019	-4.751*	-4.258**	-2.741	-6.994***
	(2.183)	(2.615)	(1.891)	(2.171)	(1.725)
Villages per Commune					
fewer than 10	-0.582	-1.479	-5.572	-17.62***	-0.951
	(3.894)	(6.703)	(4.228)	(4.393)	(3.378)
20-Nov	-0.726	0.421	-8.855***	-14.05***	-4.965*
	(2.796)	(4.540)	(2.763)	(3.083)	(2.651)
21-30	0.724	0.905	-0.694	-9.640***	0.819
	(2.942)	(3.809)	(2.583)	(2.839)	(2.410)
School Characteristics					
Primary School in Village	4.180	-1.915	2.506	0.074	-0.326
	(3.620)	(3.000)	(2.410)	(2.709)	(2.388)

Table 4.10 (Continued)

	School	Farm	Family Business	Chores	Childcare
Primary School within 1-5km	18.66***	-2.349	2.027	0.121	-1.989
	(6.135)	(3.281)	(2.636)	(3.039)	(2.912)
Primary School farther than 5km	-0.166	1.307	5.328	7.670*	2.673
	(5.899)	(4.445)	(3.438)	(4.013)	(3.620)
Multiple Primary Schools	1.219	0.775	-0.920	1.094	0.234
(1=Yes)	(1.999)	(1.844)	(1.399)	(1.601)	(1.450)
Student-Teacher Ratio	-0.008	0.052	-0.029	0.012	-0.017
	(0.039)	(0.039)	(0.029)	(0.035)	(0.030)
Repetition Rate	1.700	-8.768**	-1.148	-4.360	-3.581
	(4.016)	(4.417)	(3.862)	(4.062)	(4.145)
Exam Pass Rate-Boys	11.40***	7.296**	-3.948	-4.718	-5.610*
	(3.559)	(3.461)	(3.111)	(3.364)	(2.963)
Exam Pass Rate-Girls	-9.170***	-4.039	2.673	6.264*	5.512*
	(3.247)	(3.345)	(3.035)	(3.241)	(2.988)
Secondary School in Village	-0.0574	-6.137***	-4.056***	-2.443	-5.257***
	(1.294)	(1.747)	(1.565)	(1.502)	(1.659)
High School in Village	-3.903	-11.46***	2.672	-6.395**	0.549
	(2.454)	(3.581)	(2.299)	(2.513)	(2.073)
Constant	32.24***	8.504	16.66***	30.93***	17.86***
	(3.688)	(5.728)	(3.859)	(4.179)	(4.642)
Observations	582	802	1063	1399	728
Number of hid	379	537	640	837	467

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4.11: Impact of Shocks-Random Effects

	School	Farm	Family Business	Chores	Childcare
Large Crop Loss	0.603	3.146*	-0.292	0.808	0.011
(1=Yes)	(1.559)	(1.605)	(1.339)	(1.485)	(1.344)
Small Crop Loss	-2.154*	-0.45	-1.783	-0.842	0.033
(1=Yes)	(1.305)	(1.573)	(1.239)	(1.395)	(1.139)
Adult Male Sick	0.625	-0.676	1.671	-0.731	-0.090
(1=Yes)	(1.479)	(1.856)	(1.550)	(1.685)	(1.358)
Adult Female Sick	-0.619	3.239	2.161	1.279	-0.121
(1=Yes)	(1.631)	(2.034)	(1.713)	(1.951)	(1.810)
Child Sick	-1.067	3.966*	-1.663	1.052	-0.980
(1=Yes)	(1.683)	(2.186)	(1.766)	(2.012)	(1.925)
Observations	582	802	1063	1399	728
Number of households	379	537	640	837	467

Notes: All coefficients are marginal effects. All covariates are estimated in the regression, but only the shock results are displayed. Absolute value of z statistics are in parentheses. * significant at 10% ,** significant at 5%; *** significant at 1% .

Household shocks from either production or illness shocks have mixed effects on the distribution of children's time[37]. When production shocks are large, conditional on a child already being engaged in farm work, weekly hours increase by 3.1 hours. Smaller production shocks yield decreases in the child's weekly school hours by 2 hours. This result is not entirely consistent because there is no increase in other labor activities to compensate for the decrease in schooling time. Child labor responses to illnesses within the household also suggest that children are primarily substitutes for other children. When other children within the household are sick, children's farm

[37] In Chapter 3 of the dissertation, I examine the plausibility of the exogeneity of these shocks and several of the assumptions of the random effects model, namely strict exogeneity with a small panel. This previous analysis suggests that despite the self-reported nature of these shocks, they are plausibly exogenous.

work increased by 4 hours. The inconsistency of the production shock results are clarified by disaggregating the results by gender.

In Tables 4.12.A and 4.12.B, the impact of production and sickness shocks are further investigated by disaggregating the sample by gender. Large production shocks induce increased farm labor supply from boys by 3.2 hours, while smaller production shocks induce girls' labor to increase by 5.9 hours. There are also gender disaggregated effects on schooling as a result of production shocks. Smaller production shocks cause a reduction of 2.7 hours in boys weekly schooling. Girls' hours in school drop by 3.5 hours when an adult female is sick. When an adult male is sick, girls' hours working in the family business increase by almost 5 hours. This result suggests that as men become sick and earning potential decreases for men that women in the household, often the proprietors of small income generating business, increase their activities which require girl child labor. When other children in the household are sick, boys increase the number of hours they work on the farm (4 hours) and girls increase the number of hours the engage in chores by 5.7 hours. The gender disaggregation increases the precision of the estimates of the impact of shocks on children's time distribution. This also suggests, as argued in the previous chapter, that strong child labor substitution effects may be reinforced by poor labor market integration that prevents households from hiring in labor. This is caused by high transportation costs due to the spatial dispersion and low population density in Northern Mali.

Table 4.12.A: Conditional Schooling and Labor Supply Disaggregated by Gender

	School		Farm Work		Family Business	
Sample Restriction	Boys	Girls	Boys	Girls	Boys	Girls
Large Crop Loss	0.889	0.193	3.251*	0.705	-0.499	-0.840
	(1.753)	(2.487)	(1.795)	(2.866)	(1.519)	(2.178)
Small Crop Loss	-2.745*	-1.844	-1.673	5.883**	-1.836	-1.919
	(1.610)	(2.001)	(1.802)	(2.884)	(1.446)	(1.937)
Adult Male Sick	0.625	2.525	-0.676	-1.564	1.671	4.919***
(1=Yes)	(1.479)	(1.856)	(1.856)	(2.779)	(1.550)	(1.768)
Adult Female Sick	-0.619	-3.494**	3.239	4.703	2.161	-0.185
(1=Yes)	(1.631)	(1.757)	(2.034)	(2.934)	(1.713)	(1.929)
Child Sick	-1.067	1.681	3.966*	-2.157	-1.663	1.194
(1=Yes)	(1.683)	(2.183)	(2.186)	(3.303)	(1.766)	(2.354)
Observations	332	250	584	218	580	483
Number of hid	255	205	431	173	420	373

Notes: All coefficients are marginal effects. All covariates are estimated in the regression, but only the shock results are displayed. Absolute value of z statistics are in parentheses.
* significant at 10% ,** significant at 5%; *** significant at 1%.

Table 4.12.B: Conditional Schooling and Labor Supply Disaggregated by Gender

	Chores		Child Care	
Sample Restriction	Boys	Girls	Boys	Girls
Large Crop Loss	-0.571	1.795	-0.144	1.233
	(1.839)	(2.174)	(1.693)	(2.020)
Small Crop Loss	-0.992	-1.439	0.998	-0.0848
	(1.667)	(2.097)	(1.483)	(1.615)
Adult Male Sick	-0.731	-0.245	-0.090	0.484
(1=Yes)	(1.685)	(2.057)	(1.358)	(1.593)
Adult Female Sick	1.279	-2.097	-0.121	0.46
(1=Yes)	(1.951)	(2.148)	(1.810)	(1.877)

Table 4.12.B (Continued)

	Chores		Child Care	
Sample Restriction	Boys	Girls	Boys	Girls
Child Sick (1=Yes)	1.052 (2.012)	5.751** (2.486)	-0.980 (1.925)	-3.602 (2.622)
Observations	734	665	352	376
Number of hid	525	509	272	289

Notes: All coefficients are marginal effects. All covariates are estimated in the regression, but only the shock results are displayed. Absolute value of z statistics are in parentheses.
* significant at 10% ,** significant at 5%; *** significant at 1%.

Asset-shock interactions provide evidence about the role that different assets (durables, agricultural capital, or livestock) play in mitigating the impact of shocks on children's time allocation. Both durables and agricultural capital reduce the impact of large crop loss shocks on children's hours of school and work (Table 4.13). An additional 100,000 FCFA (USD 194) of durables reduces the hours children spend working on the farm by 1.2 per week. Agricultural capital also increases the hours that a child spends in school if exposed to a large crop loss shock by 7.5 hours. This may illustrate that responses to shocks are less labor intensive when higher levels of agricultural capital are available to the household. Livestock values have mixed, but negligible effects per 100,000 FCFA on children's domestic work when exposed to a small crop loss shock. With respect to asset–illness shock interactions (Table 4.14), higher levels of durables increase children's hours in school by .84 hours when men are sick. Increased livestock values also have a significant impact on children's work hours when adult women are sick. An additional 100,000 FCFA of livestock value decreases children's hours per week on the farm (-.97 hours), in the family business (-.5 hours), and doing household work (-.6 hours).

Table 4.13: Asset Crop Loss Shock Interactions

	School	Farm	Family Business	Chores	Childcare
Durables x Large Crop Loss	-0.103	-1.169*	-0.173	0.210	0.041
	(0.445)	(0.600)	(0.419)	(0.433)	(0.494)
Durables x Small Crop Loss	0.0189	0.291	0.183	0.137	0.170
	(0.128)	(0.808)	(0.172)	(0.201)	(0.392)
Agricultural Capital x Large Crop Loss	7.464**	5.026	0.700	1.831	4.367
	(3.673)	(3.132)	(3.633)	(3.572)	(4.342)
Agricultural Capital x Small Crop Loss	-0.694	2.971	-1.614	0.603	-0.010
	(2.842)	(2.697)	(2.003)	(2.337)	(1.732)
Livestock Value x Large Crop Loss	-0.104	-0.205	-0.462	-0.500	0.222
	(0.321)	(0.313)	(0.294)	(0.307)	(0.324)
Livestock Value x Small Crop Loss	-0.063	-0.072	-0.22	-0.246*	0.228
	(0.117)	(0.235)	(0.143)	(0.138)	(0.148)
Observations	582	802	1063	1399	728
Number of hid	379	537	640	837	467

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100 000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interaction results displayed. Absolute value of z statistics are in parentheses. * significant at 10%, ** significant at 5%; *** significant at 1%.

Table 4.14: Asset-Illness Shock Interactions

	School	Farm	Family Business	Chores	Childcare
Durables x Sick Male	0.837**	-0.509	0.644	0.068	-0.015
	(0.346)	(0.762)	(0.516)	(0.440)	(0.331)
Durables x Sick Female	0.186	1.479**	-0.148	0.685	0.276
	(0.520)	(0.664)	(0.607)	(0.417)	(0.450)
Durables x Sick Child	-0.243	-1.096	-0.422	-0.206	0.077
	(0.362)	(0.931)	(0.664)	(0.143)	(0.097)
Agricultural Capital x Sick Male	-0.102	0.14	-1.011	0.013	-0.029
	(0.116)	(0.222)	(1.160)	(0.186)	(0.116)
Agricultural Capital x Sick Female	1.659	1.904	-5.005	-1.825	0.836
	(2.544)	(3.489)	(3.093)	(3.310)	(3.004)

Table 4.14 (Continued)

	School	Farm	Family Business	Chores	Childcare
Agricultural Capital x Sick Child	-0.814	4.788	3.653	-0.799	-2.429
	(4.170)	(4.079)	(3.513)	(3.811)	(3.249)
Livestock Value x Sick Male	-0.229	0.178	-0.254	-0.399*	0.014
	(0.178)	(0.265)	(0.307)	(0.233)	(0.190)
Livestock Value x Sick Female	0.116	-0.966***	-0.518**	-0.602**	-0.286
	(0.201)	(0.358)	(0.238)	(0.246)	(0.228)
Livestock Value x Sick Child	-0.060	0.459	0.317	0.339	0.571*
	(0.201)	(0.479)	(0.251)	(0.260)	(0.345)
Observations	582	802	1063	1399	728
Number of hid	379	537	640	837	467

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100 000 FCFA, roughly 200 US$. All covariates estimated in the regression, but only asset interaction results displayed. Absolute value of z statistics are in parentheses. * significant at 10%, ** significant at 5%; *** significant at 1%.

As noted in the discussion of the econometric specification, these results should be interpreted with caution due to the cross-sectional nature of the data. However, these results are broadly consistent with the role that assets may have in an ex-post responses to shocks. Households with higher levels of durables will be able to have fewer liquidity constraints to hire in labor. However, the magnitudes of these coefficients are rather small which may reflect the difficulty of hiring in labor due to poor labor market integration or imperfect asset markets. The magnitudes of the coefficients for agricultural capital are much larger which suggests that capital intensive responses to production shocks reduces the demand for child labor. Likewise, livestock value both increases the demand for child labor by necessitating more supervision of livestock and decreases the demand for child labor by providing the household a relatively liquid asset to sell in response to idiosyncratic shocks.

Though the econometric specification is not ideal, due to data limitations, the interpretation of these coefficients is broadly consistent with theory.

Ordered Probit Results

The ordered probit model controlling for random effects is presented in Table 4.15. Note that a one unit increase in work according to a child's work intensity ranking equates to a 10% increase in work relative to schooling and leisure time. Gender has no significant impact on the child work intensity estimation. Household composition, assets and parental education have significant effects on children's work intensity. Household composition, specifically the number of boys in the household decreases the probability that children will have higher work intensities. Increased herd sizes slightly increase children's work intensity and lower the amount of time children spend in school. This may be because livestock require supervision and monitoring which are often tasks delegated to children. However, other measures of household assets including durables, agricultural capital or livestock values have no significant effect on children's work intensity.

Table 4.15: Ordered Probit — Shocks with Asset Interactions and Random Effects

	School		Work	
Asset Interactions with:	Production Shock	Health Shock	Production Shock	Health Shock
Boy Indicator	0.044	0.037	-0.096	-0.100
	(0.095)	(0.095)	(0.072)	(0.073)
Household Composition				
biological child indicator	0.092	0.098	-0.014	-0.027
	(0.131)	(0.132)	(0.096)	(0.097)
number of girls	-0.038	-0.030	0.009	0.006
	(0.053)	(0.053)	(0.038)	(0.039)
number of boys	0.033	0.039	-0.058*	-0.043
	(0.047)	(0.045)	(0.032)	(0.032)
number of Adult Men	-0.067	-0.088	0.061	0.096**
	(0.063)	(0.061)	(0.043)	(0.041)
number of Adult Women	0.079	0.068	-0.065	-0.049
	(0.065)	(0.064)	(0.046)	(0.046)
Father's Age	-0.004	-0.004	0.001	0.002
	(0.003)	(0.003)	(0.002)	(0.002)
Mother's Age	-0.000	-0.001	-0.003	-0.004
	(0.004)	(0.005)	(0.003)	(0.003)
Household Assets				
Livestock Value (FCFA)	0.003	0.023	0.007	0.009
	(0.014)	(0.015)	(0.011)	(0.011)
Herd Size (Number of Animals)	-0.008*	-0.011**	0.007**	0.006*
	(0.005)	(0.005)	(0.004)	(0.004)
Agricultural Capital (FCFA)	0.007	0.006	-0.001	-0.002
	(0.009)	(0.010)	(0.007)	(0.007)
Household Durables (FCFA)	0.006	0.004	-0.007	-0.007
	(0.009)	(0.009)	(0.007)	(0.008)
Migrant Remittances (FCFA)	-0.036*	-0.026	0.018	0.014
	(0.022)	(0.020)	(0.019)	(0.019)
Parental Education				
Any Mother's Education	0.619***	0.732***	-0.504***	-0.582***
(1=Yes)	(0.220)	(0.220)	(0.190)	(0.195)
Any Father's Education	0.632***	0.648***	-0.498***	-0.510***
(1=Yes)	(0.178)	(0.173)	(0.140)	(0.142)

Table 4.15 (Continued)

Asset Interactions with:	School: Production Shock	School: Health Shock	Work: Production Shock	Work: Health Shock
Community Characteristics				
Access to River	-0.383*	-0.317	-0.254*	-0.362**
(1=Yes)	(0.223)	(0.228)	(0.151)	(0.152)
Roads				
within 1-10km	0.345	0.393	-0.334**	-0.367**
	(0.240)	(0.241)	(0.159)	(0.158)
within 11-20km	0.334	0.371	-0.068	-0.070
	(0.304)	(0.308)	(0.190)	(0.193)
greater than 20km	0.696**	0.691**	-0.824***	-0.855***
	(0.329)	(0.335)	(0.224)	(0.228)
Commune Population				
less than 5000 people	0.361	0.371	-0.540	-0.580
	(0.532)	(0.541)	(0.381)	(0.386)
5-10,000 people	-0.063	-0.001	-0.459**	-0.552**
	(0.322)	(0.331)	(0.234)	(0.236)
10-20,000 people	0.096	0.253	-0.137	-0.208
	(0.314)	(0.315)	(0.211)	(0.212)
Villages per Commune				
fewer than 10	0.623	0.748	-0.111	-0.025
	(0.620)	(0.626)	(0.441)	(0.447)
11-20	0.246	0.284	-0.054	0.019
	(0.426)	(0.422)	(0.303)	(0.303)
21-30	0.153	0.151	0.326	0.330
	(0.396)	(0.403)	(0.282)	(0.286)
School Characteristics				
Primary School in Village	1.269***	1.249***	-0.561**	-0.502*
	(0.435)	(0.436)	(0.266)	(0.266)
Primary School within 1-5km	0.042	0.021	-0.371	-0.445
	(0.557)	(0.569)	(0.301)	(0.304)
Primary School farther than 5km	-0.911	-0.828	-0.127	-0.248
	(0.657)	(0.660)	(0.384)	(0.387)
Multiple Primary Schools	0.149	0.092	0.269*	0.400**
(1=Yes)	(0.245)	(0.249)	(0.156)	(0.158)
Student-Teacher Ratio	-0.008	-0.008	0.009***	0.009**
	(0.005)	(0.005)	(0.003)	(0.003)
Repetition Rate	0.042	-0.179	-0.247	0.052
	(0.569)	(0.575)	(0.395)	(0.400)

Table 4.15 (Continued)

	School		Work	
Asset Interactions with:	Production Shock	Health Shock	Production Shock	Health Shock
Exam Pass Rate-Boys	-0.601	-0.555	-0.231	-0.278
	(0.468)	(0.472)	(0.307)	(0.314)
Exam Pass Rate-Girls	1.087**	1.017**	-0.195	-0.202
	(0.442)	(0.445)	(0.297)	(0.302)
Secondary School in Village	0.801***	0.983***	-0.869***	-1.055***
	(0.204)	(0.203)	(0.149)	(0.147)
High School in Village	0.163	0.107	-0.468*	-0.552**
	(0.343)	(0.351)	(0.252)	(0.259)
Asset Shock Interactions				
Durables x Large Crop Loss	0.110**		-0.081**	
	(0.053)		(0.035)	
Durables x Small Crop Loss	0.019		-0.017	
	(0.025)		(0.021)	
Agricultural Capital x Large Crop Loss	-1.085**		0.464*	
	(0.448)		(0.282)	
Agricultural Capital x Small Crop Loss	-0.183		0.256	
	(0.356)		(0.235)	
Livestock Value x Large Crop Loss	0.098***		-0.054**	
	(0.037)		(0.025)	
Livestock Value x Small Crop Loss	0.031**		-0.019	
	(0.015)		(0.014)	
Durables x Sick Male		0.017		-0.078*
		(0.051)		(0.046)
Durables x Sick Female		0.064		-0.059
		(0.070)		(0.044)
Durables x Sick Child		-0.021		-0.010
		(0.043)		(0.015)
Agricultural Capital x Sick Male		-0.002		0.017
		(0.023)		(0.020)
Agricultural Capital x Sick Female		-0.404		-0.073
		(0.408)		(0.301)
Agricultural Capital x Sick Child		-0.236		0.690*
		(0.595)		(0.368)

Table 4.15 (Continued)

	School		Work	
Asset Interactions with:	Production Shock	Health Shock	Production Shock	Health Shock
Livestock Value x Sick Male		0.003		-0.005
		(0.032)		(0.024)
Livestock Value x Sick Female		0.063*		-0.051**
		(0.033)		(0.026)
Livestock Value x Sick Child		-0.064*		0.029
		(0.033)		(0.029)
Observations	1626	1626	1626	1626

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 US$ District population, number of villages per commune, ethnicity and seasonal indicators are included in the regression, but results are not displayed. Robust standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Parental education also affects children's work intensity. Both mother's and father's education has significant effects on lowering the probability that a child increases their work intensity one category by .50 and .49, respectively. Parental education also increases the proportion of time the child spends in school. An increase of one decile of time spent in school is .62 more likely when the child's mother has been educated or .63 when the child's father has been educated. School characteristics such as having a primary or secondary school in the village increase children's school intensity and reduce work intensity.

Household crop and health shocks, both of which may cause unexpected decreases in income, increase the intensity of children's work, suggesting that children are used as insurance against unexpected income fluctuations (Table 4.16). However, the intensity of the crop shock and the household member affected by the health shock determine the responsiveness of children's work. Large crop shocks increase the probability that a child will have a higher work ranking by .58 while small crop losses have no significant effects. Morbidity shocks to other children in the household also increase children's work intensity, raising the probability that they will be at a higher subjective ranking by .31.

Table 4.16: Ordered Probit with Random Effects and Shocks

	School	Work
Large Crop Loss	-0.309	0.584***
(1=Yes)	(0.207)	(0.142)
Small Crop Loss	0.0871	0.201
(1=Yes)	(0.194)	(0.139)
Adult Male Sick	0.071	0.0108
(1=Yes)	(0.188)	(0.140)
Adult Female Sick	-0.0152	-0.0769
(1=Yes)	(0.211)	(0.150)
Child Sick	-0.36	0.310*
(1=Yes)	(0.225)	(0.163)
Observations	1626	1626

Notes: All coefficients are marginal effects. All coefficients of variables valued in FCFA are multiplied by 100000 FCFA, roughly 200 USD. All covariates are included in regression, but coefficients are not reported for brevity.

Asset-shock interactions by households provide evidence about the role that different asset and shock types may have on child labor and school intensity. These results are presented in Table 4.15. Durables lower the selection probability that a child increases work intensity in response to large crop shocks by 8.1% for each additional 100,000 FCFA of asset value that the household owns. For the same increment of durables, a 11% greater probability was estimated that a child will report increased schooling intensity in the face of a large production shock. Agricultural capital value interacted with a large crop loss had negative effects on children's school and positive effects on children's work intensity, but the estimated effects were much larger (-1.085 and .464, respectively). Households with higher levels of agricultural capital may have more ex-post smoothing mechanisms, but these strategies inevitably require labor for which children may be an available source. Livestock values, like durables, increased the probability that the child spent more time in school and less time working in the face of large production shocks. Smaller production shocks interacted with assets had no significant effects on the subjective assessments of children.

When asset-illness shock interactions are estimated, an increase of 100,000 FCFA in durables lowers a children's subjective work ranking with probability 7.8% when an adult male is sick. Livestock value interacted with women's sicknesses also mitigate the effects of increased labor demands from the households on children. The probability that a child reports a lower level of work is decreased by 5.1% for each additional 100,000 FCFA of livestock value and higher levels of schooling by 6.3%. When another child falls ill, increased livestock values decrease the intensity of children's schooling time by 6.4%. However, agricultural capital interacted with other children's sickness increases the probability that a child has a higher work ranking by 69%.

VII: Conclusions

Child labor substitution effects caused by exposure to shocks have potentially large welfare implications for children and longer term intergenerational effects for children of undereducated parents. The empirical results presented in this chapter show less compelling labor substitution patterns than in the participation data. This suggests that households add workers to increase labor supply as a first response rather than increase the hours of household members already working in an activity. However, if measurement error contaminates the hours data, then increased variability of results, without biasing coefficient estimates, could explain less statistically significant patterns. As an alternative to hours data, the subjective module data is consistent with participation data presented in Chapter 3, since it may minimize proxy respondent bias from parents.

Subjective evaluations by children indicate that when their household faces a production shock, their work time increases and schooling time decreases. Durables and livestock assets increase children's time in school and decrease their work time in the face of large production shocks. This suggests that these asset stock help mitigate child labor responses to shocks. However, stocks of agricultural capital have the opposite effect. In the face of large production shocks, children work more when their families have access to agricultural capital which presents a specific challenge to the program design of development interventions in northern Mali. Because of widespread food insecurity due to a lack of public investment and poor agro-ecological conditions, agricultural interventions often have as objective to increase agricultural productivity by increasing the farmer's agricultural capital. While the farmer may be more productive, it also requires more labor inputs, especially when exposed to production shocks. Programs should be aware that farmers not only require assistance in increasing farm production, but decreasing the variability of production caused by crop loss shocks. Linking interventions to continued school enrollment or providing crop insurance would be one program design feature that would minimize the impact of increased labor demand on children when households are exposed to production shocks.

Given other evidence from social protection programs (de Janvry et al. 2006, Ravallion and Wodon 2000), this suggests an important continued area of child labor research into how households may use child labor as an ex-post response to idiosyncratic shocks, even with access to social protection or other development interventions designed to minimize exposure to risk.

CHAPTER 5: ACCESS TO IRRIGATION AND THE ESCAPE FROM POVERTY: EVIDENCE FROM NORTHERN MALI

I. Introduction

Empirical evidence suggests that irrigation projects have positive impacts on agricultural production and the reduction of poverty for farmers (von Braun, Puetz, and Webb 1989; Hussain and Hanjra 2004; Smith 2004; Lipton 2007; and Hussain 2007b). Access to irrigation provides farmers with a reliable water source at critical times in the crop's life cycle, removing the dependence and inherent uncertainty of rainfed and lake-based agricultural systems in arid and semiarid regions of northern Mali. This reduction in risk faced by farmers is likely not only to increase mean agricultural returns but also to reduce their vulnerability to income fluctuations. While farmers are exposed to unforeseen production shocks regardless of the production system, irrigation minimizes these shocks by permitting a wider range of ex-post smoothing mechanisms to be used, which causes fewer distress sales of crop stocks or assets. Lipton (2007) reports that in India, irrigated areas had 2.5 times lower standard deviation of crop output per year during the period 1971—84.

Because irrigation investment is not homogeneous between or within countries, this paper contributes to the literature on the impact of internationally financed irrigation projects on household agricultural production, household consumption, and nutrient intakes in northern Mali, an area that possesses few of the preconditions for agricultural growth, such as good quality soil, frequent and adequate rainfall, moderate temperatures, and sufficient infrastructure. Most international attention has been paid to the Office du Niger irrigation scheme[38] in the Segou region of Mali. However, small-scale village-level projects (30–40 hectares) and larger-scale projects (500 hectares) dot the inner Niger delta and north of Tombouctou into the Saharan desert, which is one of the poorest regions of Mali and an area hardest hit by the Sahel droughts[39]. These irrigation projects are not investments by farmers in boreholes or wells for irrigating their personal fields; rather they are community-level investments that result from household, village, and international organization partnerships. Borehole or well investment by households is less frequent in northern Mali because of its arid climate, which results in a low water table and increased difficulty in constructing wells. The dominant type of irrigation project considered here are those that use motorized pumps to redistribute water from the Niger River throughout a canal irrigation system.

The analysis in this paper is based on field research, including a multi-topic household survey in northern Mali, conducted in 1997–98[40] and again in 2006. Because these data were not generated as a random experiment, several identification problems exist, which the econometric strategy attempts to control. The first is the endogeneity of access to irrigation due to nonrandom program placement. This bias occurs when intentional or implicit targeting rules are used to allocate projects to villages. These village-level characteristics are more likely to correlate with the explanatory variables

[38] The Office du Niger was originally constructed in 1932 as a gravity irrigation scheme during French colonialism. While widely regarded as a failure into the early 1970s, a restructuring of the Office du Niger from 1979 to 1996 has improved the technical efficiency of the institution and increased grain yields for farmers (Couture, Lavigne Delville, and Spinat 2002).

[39] Understanding the effectiveness of these projects is not only of economic importance but also political importance. The Government of Mali has used investment in irrigation and infrastructure in Northern Mali as a strategy to bring peace to an area of social unrest caused, in part, by economic destitution.

[40] These data, originally collected by Luc Christiaensen with support from John Hoddinott, have been made available by the International Food Policy Research Institute (IFPRI) (Christiaensen 1998)

if the programs are allocated either to highly productive areas to ensure program success or to less productive areas to target the poor. In either case, estimates of the project impact derived from outcome indicators will contain upward or downward bias, respectively, due to the group's pretreatment characteristics.

A second source of bias in program estimates is the selection bias due to non-mandatory program participation. Access to irrigation is likely to be correlated with household characteristics such as education, which may influence the likelihood of technology adoption or the ability of a farmer to lobby on behalf of his community for the intervention; access to water, which is a necessary condition for motorized irrigation; and whether households live in rural or urban areas, which may increase the facility of program implementation. Program placement is not random. Unless the allocation of program interventions was intentionally randomized or can be viewed as a natural experiment, the distribution of observable and unobservable village and household characteristics between treatment (with irrigation) and comparison groups (without irrigation) will not be statistically equivalent.

The econometric strategy employed to address the nonrandomized program placement in villages and adoption decisions by households within these villages is threefold. Difference in differences, propensity score matching, and matched difference-in-differences estimators are estimated, drawing on a growing theoretical and empirical literature on the estimation of program effects from non-experimental data (Heckman, Ichimura, and Todd 1997; Smith and Todd 2005; Bertrand, Duflo, and Mullainathan 2004; Jalan and Ravallion 2003; and Gilligan and Hoddinott 2007). As a robustness check for the propensity score matching and matched difference-in-differences estimates, four different estimators (nearest-neighbor matching, matching with 10 closest neighbors, kernel Epanechnikov, and local linear matching are employed to produce point estimates. Estimates of the impact of irrigation are robust to both econometric strategy and choice of estimator. Despite these robustness checks, it should be noted that the fundamental role that unobservables may have in driving these relationships is not adequately addressed by difference in differences or propensity score matching. Because irrigation investments were not allocated to villages randomly and participants were not selected into plots randomly,[41] the paper cannot completely rule out the question of whether unobservable characteristics drive the relationship. However, because allocation of village-level projects is predicated on proximity to the Niger River, there are strong observable characteristics that facilitate the construction of legitimate treatment and comparison groups.

Besides measuring the impact of irrigation, this paper attempts to reconcile differences in impact assessments made using agricultural production and household consumption. Because increases in agricultural production do not necessarily transfer one-to-one into gains in household consumption, critics of irrigation suggest that increased input costs erode the benefits of irrigation projects (Kouyate and Haidara 2006). However, empirical evidence from other antipoverty programs suggests that if a participant's time horizon is sufficiently short, the program may be viewed as a temporary intervention, yielding no changes in a participants' permanent income (Ravallion and Chen 2005). This paper investigates the hypothesis that households may save surpluses in agricultural production by accumulating livestock. Alternatively, irrigators sharing additional food gained from irrigation with non-irrigators in their village could also explain the discrepancy between average effects of

[41] Although in most villages, after the irrigation scheme is built, participants are allocated an irrigated plot randomly in the village scheme. This controls, at least, for differences in unobserved soil quality among adopters.

irrigation on production and consumption. Either hypothesis would understate the gains from irrigation if household consumption were used as the sole measure of welfare. As part of a study of potentially offsetting secondary effects of irrigation, the paper examines whether access to irrigation increases the demand for child labor and induces changes in household composition due to increased labor demands.

This paper's organization is standard. The second chapter presents a household model of agricultural investment and risk. The third chapter describes the data and survey area. Chapter 4 presents the econometric strategy. Chapter 5 presents the estimates of the direct effects of irrigation on household consumption, agricultural production, and nutrient intakes and discusses the secondary effects of irrigation, including livestock accumulation, food sharing within villages, household composition, and child labor. These variables measure potential ex-ante changes to household savings behavior, informal insurance networks, and labor demand induced by access to irrigation. A final chapter concludes the paper.

II. A Model of Irrigation Investment and Risk

Rosenzweig and Binswinger (1993) propose a theoretical model to investigate the relationship between risk and agricultural investment. In this paper, the model is applied to irrigation investments made jointly by international organizations and village agricultural producers to install irrigation schemes. Sensitivity to risk is captured in the theoretical framework by modeling farm households whose utility function values not only mean consumption over time but also the variability of this consumption.

Consider a farm household that maximizes utility over mean consumption, $\mu_{c,}$ and wants to minimize the standard deviation of consumption, σ_c. The farm household maximizes a utility function *V* such that:

$$U = V(\mu_c, \sigma_c)\,, \tag{5.1}$$

where $V_\mu > 0$ and $V_\sigma < 0$. The farmer produces output by choosing productive investments I_i, where $i = 1,..., N$, such as fertilizer, irrigation, or high-yielding seeds. Meyer (1987) and Meyer and Rasche (1992) show that this mean-standard deviation approach is equivalent to expected utility maximization under the location and scale parameters condition. That is, when random variables differ only by location and scale, rankings based on expected utility or moments of the distribution are consistent. The farm household realizes a profit from investment decisions such that:

$$\pi = pf(x, I_i) - wx\,, \tag{5.2}$$

where *p* is the vector of output prices for the production function, $f(x, I_i)$, which produces a vector of outputs. The production technology, $f(.)$, transforms inputs *x*, such as labor, purchased at cost, *w*. $f(.)$ has a positive first derivative and a negative second derivative. Agricultural investments, I_i, are assumed to exhibit constant returns to scale in the production function. Households allocate a fraction of their wealth, *W*, to agricultural technology. This is determined by the function $g(\alpha_i)$, where α_i is a vector of the value share of investment opportunity *i* from total wealth, *W*. This term $g(\alpha_i)W$ does not enter the profit function as a cost because it is a portfolio allocation of wealth.

Agricultural risk is characterized as a mean, μ_r , and a standard deviation, σ_r. Then, following Rosenzweig and Binswanger (1993), the mean and standard deviation of farmers' profits given by Equation 5.2 is:

$$\mu_\pi = g(\alpha_i) W \mu_r \, , \tag{5.3}$$

$$\sigma_\pi = \Gamma(\alpha_i) W \sigma_r \, , \tag{5.4}$$

where $\Gamma(\alpha_i)$ measures the riskiness of the investment portfolio. Assume also the second derivatives of $g(\alpha_i)$ and $\Gamma(\alpha_i)$ are less than zero. Then the mean of consumption is

$$\mu_c = \eta(S, N) \mu_\pi \, , \tag{5.5}$$

where mean agricultural profits, μ_π , are scaled by a function that allocates a fraction of mean profits between household savings, *S*, and intravillage sharing according to social norms, *N*. The standard deviation of consumption is

$$\sigma_c = \kappa(W) \, \sigma_\pi \, , \tag{5.6}$$

where $\kappa(W)$ is a function of wealth that interacts with the standard deviation of profits, and it is assumed that $\kappa'(W) < 0$, or increased wealth, mutes the effects of changes in the standard deviation of profit on the standard deviation of consumption. The standard deviation of agricultural profits scaled by a function of wealth [$\kappa(W)$] varies with the standard deviation of consumption to permit a wide variety of assumptions concerning financial markets. If $\sigma_c = \sigma_\pi$ (that is, $\kappa(W) = 1$), the illiquidity of the asset market is implicitly assumed. The alternative assumption would be that $\sigma_c = 0$, which implies that households can fully insure against income uncertainty.

Since V is quasi-concave, the first-order conditions are given by

$$V_{\mu}\eta(S,N)g'(\alpha_i) = -V_{\sigma}\Gamma'\kappa(W)\sigma_r \,. \tag{5.7}$$

Profit maximization requires that $g'(\alpha_i) = 0$, since $g'(\alpha_i) = g_i - g_{i+1}$, the marginal contribution to mean profits must be equalized across investments, given the optimality of farmer decisions. Since the right-hand side of the equation is negative, farm households who are risk averse, with a diverse portfolio of investments, have mean profits that will be lower than optimal. That is, farmers pay a premium to reduce risk, which is the difference between optimal mean profits and mean profits that result from the solution to equation (5.7).

Consider now an irrigation investment that has a high fixed cost but a large mean profit return and a reduction in the standard deviation of profits. Farm households will clearly undertake the investment, given the quasi-concavity of the utility function if $W > C$, where C is the cost of the irrigation investment. However, if borrowing constraints exist and C is larger than W, which it will often be for mechanized irrigation projects, then a net social welfare loss is sustained by beneficiaries of the project (B) if

$$\sum_{i=1}^{B}\mu_{\pi}^{I} - \sum_{i=1}^{B}\mu_{\pi}^{N} \geq C \,, \tag{5.8}$$

and

$$\sum_{i=1}^{B}\frac{\sigma_{\pi}^{I}}{B}-\sum_{i=1}^{B}\frac{\sigma_{\pi}^{N}}{B}\leq 0\,. \tag{5.9}$$

Equations 5.8 and 5.9 state, first, that for irrigation investment to be an efficient investment, the difference between mean profits from irrigation, aggregated across all beneficiaries, and the next greatest mean profit from an investment, aggregated across all beneficiaries, ought to be larger than the cost of the irrigation investment. Second, the mean variance of the irrigation investment for beneficiaries should be less than the mean variance from the next most profitable investment opportunity. However, there also may be cases where the difference in mean profits between irrigators and non-irrigators is large enough that, even if the standard deviation of profits is larger than that for non-irrigators, an irrigation investment would still increase social welfare. This case may exist because learning by doing from newer irrigation adopters will create higher variability in profits or the crop choice induced by irrigation, such as rice, has higher variance in yield due to its greater sensitivity to inputs (water, fertilizer, timing of labor inputs) then other rain-fed crops like millet.

What this model does not address is how households choose to allocate their additional surplus. Surplus from profitable investments can be consumed, saved, or shared with other villagers, as a form of altruism or quasi-insurance against idiosyncratic shocks. In addition to testing the impact of irrigation investments on agricultural production, consumption, and nutrient intakes, this paper investigates whether households allocate unconsumed agricultural surplus to savings or to intravillage sharing. It also estimates the average treatment effects of irrigation on child labor, a potentially negative secondary effect of irrigation, caused by increased labor demand by irrigators.

III. Survey Area and Data Description

The data for this paper were collected as part of the Poverty and Food Security Household Survey in Northern Mali 2006 (*Etude sur la Pauvreté et la Sécurité Alimentaire au Nord Mali 2006*) conducted by the author. This multitopic household survey was implemented to study household behavior related to human capital formation and agricultural production in northern Mali. Of the 2,658 households in the sample, 245 households in the commune of Soboundou, Niafunke, that were originally surveyed in a similar study conducted in 1997–98, were resurveyed twice in 2006. Sample attrition from the 1997–98 round was 12 percent, which is within the bound of attrition commonly found by other surveys (Alderman et al. 2000). Further details related to tracking households from the 1997–98 survey and detailed methodological documentation of the survey design and implementation can be found in Dillon (2005) and in the previous chapter of this paper.

The data set is composed of a village questionnaire and a household questionnaire. The village questionnaire was administered to village leaders in each village or town included in the study. The household questionnaire was divided into men's, women's, and children's sections and was addressed to the head of household and the head of household's wife and children, respectively. Data were collected on a wide range of variables to analyze the household's agricultural production, income-generating activities, livestock, assets, education, health, and demographic composition. Questions concerning the household's composition, education, primary activities, migratory status of household members, and history of positive and negative economic shocks were addressed to the head of household, usually a man. Questions concerning the household's food consumption, meals shared between households, and health and dietary diversity were addressed to women. Sections concerning possessions, nonfood expenditures, agricultural production, herding activities, credit, and time allocation were addressed to both men and women.

Agroecological conditions throughout most areas of Northern Mali would not be favorable for agricultural production without the Niger River, which is the dominant ecological resource in the region. The inner Niger Delta is a potentially productive agricultural area in which flooding from the Niger augments water levels in temporary and permanent lakes and ponds, as well as smaller streams and tributaries. Land quality deteriorates as the distance from the river increases. Farmers harness water resources through motorized pump irrigation and the use of water-recession agriculture around the lakes and streams and in the Niger River itself, as its water levels decrease seasonally. Rain-fed agriculture that does not depend on the water levels of the Niger River is also extensively practiced. However, rain-fed agriculture is a difficult endeavor. The Saharan zone (a desert or arid region) receives less than 150 millimeters of rainfall per year. This varies starkly with the Sahelien zone (a grassland or semi-arid region), which receives 200–600 millimeters per year, and the south of Mali, which can receive as much as 600—1,200 millimeters per year (Christiaensen 1998).

Despite persistent poverty in northern Mali, it is important to note that the agricultural sector has not remained static over the past eight years. Table 5.1 illustrates the distribution of water control systems used by farmers in northern Mali. Since 1997, the agricultural sector has shifted toward irrigated agriculture, with a 30 percent increase in access to irrigation in the sample studied. While the utilization of rain-fed agriculture has remained somewhat constant, producers using lake-based systems have substantially declined. The increasing number of producers using solely a lake-based system is swamped by the decline in those using lake and rain-fed systems in tandem. The increase in use of irrigation correlates with the increase in irrigation investment by international nongovernmental organizations (NGOs), which began making irrigation investments in the late 1990s, as a post-conflict development strategy following the Touareg Rebellion.

Table 5.1: Utilization of different agricultural production systems
(% of farmers who use the different systems)

	1997–98	2005–06
Irrigation	0.4%	30%
Lake	6.8%	18.50%
Rainfed	35.0%	33%
Irrigation and lake	0.0%	1%
Irrigation and rain	9.4%	10%
Lake and rain	41.9%	6%
Irrigation, lake, and rain	6.4%	2%

Notes: N = 246. The different agricultural systems are defined by the system that the farmer uses to water his plot. These include a strictly irrigated system, a lake system, rainfed agriculture, and combinations of these three.

Production is highly labor-intensive with low levels of agricultural capital available to households. Median agricultural capital is approximately 32,000 CFA francs (FCFA) per household, or 70 US dollars. Other factors that contribute to higher agricultural productivity include labor inputs, crop choice, area cultivated, and input utilization. The median household uses 225 days of labor to cultivate 1.4 hectares. Median expenditures on seed, fertilizer, pesticide, and manure inputs are 26,248 FCFA

(US$58) with the majority of input expenditure spent on seed and fertilizer. These low levels of input utilization reflect a multiplicity of farming constraints, including limited access to inputs and technical capacity for appropriate inputs, as well as credit constraints.

In the survey area, access to irrigation is facilitated by international organizations and NGOs who provide motorized pumps to villages at no charge or significantly discounted prices, which are then reimbursed over an extended period of time and with the condition that villages contribute labor for the construction of the irrigation infrastructure, undertake pump maintenance, and provide fuel for the pump's operation. Irrigation is primarily used for rice cultivation, rather than sorghum or millet, two traditionally rain-fed crops. Rice production that relies on irrigation is cropped once per agricultural cycle. Internationally, increased agricultural production from a dual cropping system is commonly cited as a benefit of irrigation. However, the arid context in northern Mali does not allow a second cropping season after rice cultivation. This is because temperatures in the dry season are high (in excess of 40^{o} C) and receding river levels make it impossible to provide the minimum water required for rice plants or other cash crops. The benefits of irrigation in northern Mali are accrued through increased water supply and control during the primary agricultural season.

Table 5. 2 investigates the relationship between agricultural production and household consumption descriptively. Mean agricultural production is 2.1 tons, compared with 643 kilograms using a lake-recession system, or 288 kilograms using rainfed agriculture. Mean total annual household consumption (2,085,778 FCFA) is also highest when farmers use irrigation. Farmers who use ng rainfed agriculture have

slightly higher household consumption than those who use lake-recession agriculture, but the difference is only 23,000 FCFA (less than US$50) over an entire year. The standard deviations of both agricultural production and consumption are higher under irrigation than under the two other water-control systems. Differences in farmer's skills may also generate greater variation in household production and consumption variables, because rice cultivation requires cultivation of seedlings that then must be replanted with appropriate space between plants in the irrigated plot. Rice seedlings are also highly sensitive to the timing and dosages of fertilizer. Despite the higher standard deviations of consumption and production, the high means of agricultural production with irrigation relative to other water-control systems indicates that rice production is not necessarily a higher risk investment for the farmer. This is because the standard deviation may not be equivalent to "risk," when farmers evaluate both the mean yield and standard deviation of a different agricultural technology before adopting.

Table 5.2: Total household agricultural production and consumption in 2006, by water control system

Total Household Agricultural Production	Mean	Standard deviation	25th Percentile	50th Percentile	75th Percentile
Irrigation	2,147.4	1,649.9	1,188	1,725.9	2,400
Lake-recession	643	933.5	157.5	270	679.5
Rainfed	288.4	283.3	121.3	196	406.7
Total	1202.1	1473.5	196	620.4	1758.9

Table 5.2 (Continued)

Total Household Consumption	Mean	Standard deviation	25th Percentile	50th Percentile	75th Percentile
Irrigation	2,085,778	1,490,314	1,180,530	1,938,500	2,615,860
Lake-recession	1,356,355	844,554	698,200	1,141,015	1,758,480
Rainfed	1,586,750	1,027,597	728,150	1,500,581	2,150,700
Total	1,724,158	1,221,531	785,500	1,501,691	2,254,350

Notes: N=246. Total household agricultural production is measured production of male and female household plots during the 2005/06 agricultural season in kilograms. Total household consumption is the annualized household consumption aggregate calculated from men and women's assets, non-food and food expenditures following Deaton and Zaidi (2002).

Because of the labor intensity of farm production in northern Mali, lack of inputs, high rice prices relative to other cereals, and large differences (more than 1 ton) in production per hectare between rice and other grains, investment in irrigation is likely to have a high return. Table 5.3 illustrates changes in total agricultural production and nutrient intakes between the 1998 and 2006 surveys by village. The percentage of households with access to irrigation in 2006 by village is reported in column 3 of Table 5.3. Villages with access to irrigation had dramatic increases in agricultural production and daily household caloric intake, with the exception of the village of Ouaki. For the entire sample, however, the mean household daily caloric intake increased by only 138 calories over the eight years between the surveys.

Table 5.3: Descriptive statistics: Access to irrigation, agricultural production, and caloric intake by village

Village	Number	Percentage of Households with Access to Irrigation in 2006	Total Agricultural Production, 1997–98	Total Agricultural Production, 2005–06	Total Daily Household Calories, 1998	Total Daily Househol d Calories, 2006
Aldianabangou	15	0	61.3	156.3	8,354	7,752
Tomba	36	68	61.1	2,309.0	4,888	6,309
Mangourou	27	0	154.3	192.4	5,295	5,588
Gouaty	7	0	54.6	359.3	4,682	8,252
N'goro	54	0	417.0	377.6	6,206	5,425
Tomi	12	75	757.9	2,735.4	5,744	8,389
Hamakoira	17	59	309.7	2,006.2	5,716	9,285
Goundam Touskel	12	0	962.4	962.5	8,000	6,293
Ouaki	47	28	1,060.5	1,022.6	6,833	5,639
Anguira	19	0	213.3	674.3	4,141	3,885
Total	246	0.24	447.1	1,028.2	6,048	6,186

Notes: Agricultural production is calculated as in the previous table. Daily household calories are imputed from food intake data.

Tables 5.4.A and 5.4.B disaggregate changes in real consumption by initial quartiles to assess whether gains or losses in consumption were equally distributed across the quartiles. Total household consumption is adjusted using a Paasche price index of grain prices.[42] Since budget shares for the households in the sample range from 73 to 88 percent of the household budget, this approximation is an adequate representation of the real prices facing households. In all the villages with access to irrigation, the largest percentage changes in real consumption occurred at the lowest quartile. Changes in consumption for the lowest quartile with irrigation range between 29.8 and 61.4 percent, while the rate of change for the whole sample is only 23.3 percent.

[42] A Paasche price index is constructed that is composed of rice, sorghum, and millet prices and quantities from the 1998 and 2006 survey rounds, following Deaton and Zaidi (2002).

Table 5.4.A: Descriptive statistics: Total real consumption by village and expenditure quartile

Village	Variable	Consumption 1998	Consumption 2006	% Change
Aldianabougou	N	15		
	25th Percentile	457,310	414,612	-10.30%
	50th Percentile	571,500	699,878	18.30%
	75th Percentile	890,485	1,023,894	13.00%
Tomba*	N			
	25th Percentile	236,204	391,448	39.70%
	50th Percentile	398,780	487,046	18.10%
	75th Percentile	574,528	727,867	21.10%
Mangarou	N	27		
	25th Percentile	252,360	355,582	29.00%
	50th Percentile	282,648	516,960	45.30%
	75th Percentile	376,765	756,938	50.20%
Gouaty	N	7		
	25th Percentile	70,485	214,187	67.10%
	50th Percentile	167,278	788,450	78.80%
	75th Percentile	772,840	1,194,649	35.30%
N'goro	N	54		
	25th Percentile	370,373	272,836	-35.70%
	50th Percentile	603,695	416,862	-44.80%
	75th Percentile	963,610	563,961	-70.90%

Notes: * denotes villages with access to irrigation. Total household consumption is the annualized household consumption aggregate calculated from men and women's assets, non-food and food expenditures following Deaton and Zaidi (2002). Real consumption aggregates were calculated using a Paasche price index as described in the text.

Table 5.4.B: Descriptive statistics: Total real consumption by village and expenditure quartile

Village	Variable	Consumption1998	Consumption 2006	% Change
Tomi*	N		12	
	25th Percentile	234,075	443,177	47.20%
	50th Percentile	347,885	672,364	48.30%
	75th Percentile	551,365	849,806	35.10%
Hamakoira*	N		17	
	25th Percentile	177,560	459,855	61.40%
	50th Percentile	368,765	654,008	43.60%
	75th Percentile	478,750	980,372	51.20%
Goundam Touskel	N		12	
	25th Percentile	234,560	380,632	38.40%
	50th Percentile	362,880	526,776	31.10%
	75th Percentile	540,273	710,009	23.90%
Ouaki*	N		47	
	25th Percentile	204,490	291,196	29.80%
	50th Percentile	341,265	430,489	20.70%
	75th Percentile	544,673	660,106	17.50%
Anguira	N		19	
	25th Percentile	110,740	199,824	44.60%
	50th Percentile	188,075	285,570	34.10%
	75th Percentile	364,305	529,828	31.20%
All Villages	N		246	
	25th Percentile	252,360	329,119	23.30%
	50th Percentile	399,070	482,522	17.30%
	75th Percentile	613,710	714,636	14.10%

Notes: * denotes villages with access to irrigation. Total household consumption is the annualized household consumption aggregate calculated from men and women's assets, non-food and food expenditures following Deaton and Zaidi (2002). Real consumption aggregates were calculated using a Paasche price index as described in the text.

Figures 5.1 to 5.3 provide descriptive evidence of the differences in the kernel densities for total household consumption, agricultural production, and total livestock units held by the households, disaggregated by access to irrigation. The dashed lines represents the density of the comparison group of households without irrigation in 2006, while the solid line represents the density of households with access to irrigation in 2006. The shapes of these densities are relatively similar; however the means are clearly higher in the irrigation densities. These density estimates are only descriptive, in the sense that none of the selection bias is accounted for by disaggregating the densities according to irrigation access. In the next chapter, different econometric strategies for estimating the returns to irrigation on production, consumption per capita, and nutrient intakes are discussed, controlling for selection bias and endogenous program placement.

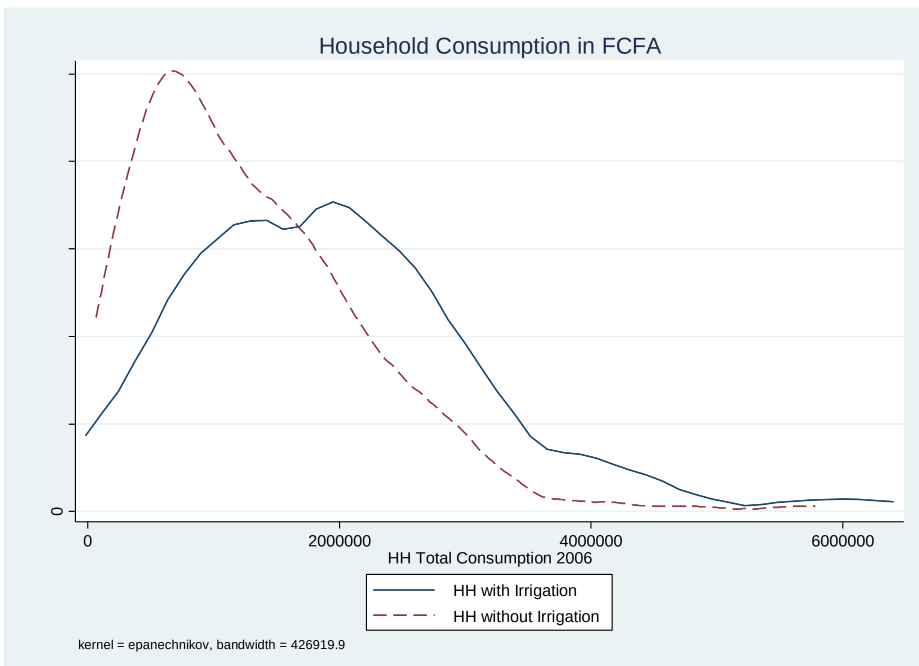


Figure 5.1: Kernel density estimates of total household consumption (in FCFAs) for households with and without irrigation

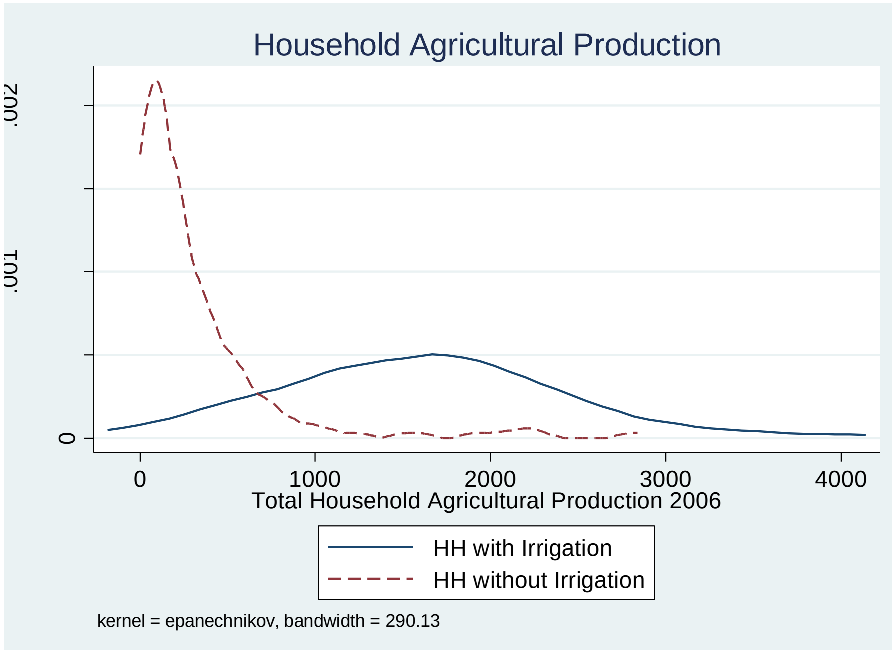


Figure 5.2: Kernel density estimates of total household agricultural production for households with and without irrigation

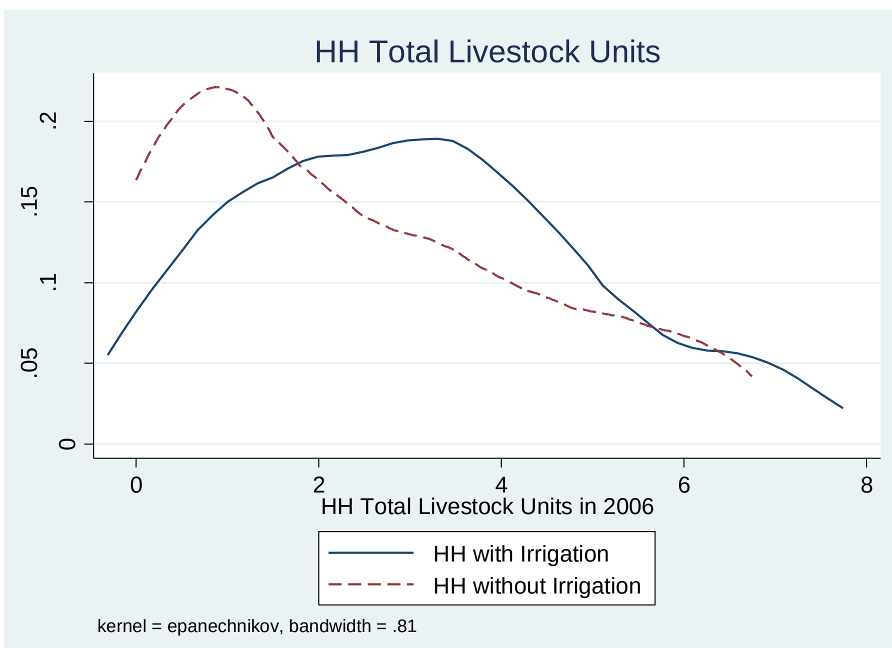


Figure 5.3: Kernel density estimates of total household livestock units for households with and without irrigation

IV. Estimating Treatment Effects Using Nonexperimental Data

To estimate average treatment effects, recognizing the problem of selection bias between treatment and comparison groups, one ideally wants to estimate $\Delta = Y_t^1 - Y_t^0$, which is the difference of the outcome variable of interest at time *t* between two treatments, denoted by the superscripts 1 and 0. However, the econometrician is unable to estimate Δ in this way because a household cannot receive two treatments simultaneously. The evaluation problem is one of missing data, due to the impossibility of assigning households to both treatment and control groups. The econometrician is forced to measure the average treatment effect (*ATE*) given the observable data:

$$ATE = E(Y_t^1 \mid T = 1) - E(Y_t^0 \mid T = 0) . \tag{5.10}$$

When data are generated through a properly implemented random experimental design, the expectations of the treatment and comparison groups are equal because the groups are composed of randomly allocated members, ensuring that the distribution of observable and unobservable characteristics of the groups are equivalent in a statistical sense. With a randomized design, the selection bias, $E(Y_t^1 \mid T = 1) - E(Y_t^0 \mid T = 0)$, equals zero, which establishes that the estimate of the average treatment effect provides an unbiased estimate of its impact.

Randomized experiments are not always possible or plausibly implemented, so that absence of selection bias is a credible assumption. Hence, applied econometricians are often forced to estimate the average treatment effect on the treated households (*ATT*), given a vector household characteristic, X :

$$ATT = E(\Delta \mid X, T = 1) = E(Y_t^1 - Y_t^0 \mid X, T = 1) = E(Y_t^1 \mid X, T = 1) - E(Y_t^0 \mid X, T = 0)\,, \tag{5.11}$$

where, because $E(Y_t^0 \mid X, T = 1)$ is unobservable, it is assumed that:

$$E(Y_t^0 \mid X, T = 1) = E(Y_t^0 \mid X, T = 0)\,. \tag{5.12}$$

Difference in differences, propensity score matching, and difference-in-differences matching estimators require identification assumptions with nonexperimental data. An important body of literature has tested these nonexperimental estimators against experimental benchmarks and against each other (see, for example, Heckman, Ichimura, and Todd 1997; Bertrand, Duflo, and Mullainathan 2004; Smith and Todd 2005; and Diaz and Handa 2006. Nonexperimental estimators can perform well if the set of observable characteristics is rich enough to create valid treatment and comparison groups. The advantages and disadvantages of these estimators are described below.

Difference-in-Differences

The difference-in-differences (DID) estimator is estimated by comparing the mean changes between treatment and control groups over two periods. The DID estimator controls for treatment group fixed effects by differencing. However, the DID estimator assumes that rates of change between the two groups would have been the same without the development intervention. The identification of this estimator requires the following three assumptions (Smith and Todd 2005). The first is that there are no differences in unobservables between the treatment and comparison groups $E(\varepsilon_{h1} - \varepsilon_{h0}) = 0$. The second is that there is no interaction between the observables and the treatment $E[(\varepsilon_{h1} - \varepsilon_{h0})T] = 0$. Lastly, identification of the difference-in-differences estimator requires that there is no interaction between the differences in unobservables and the observable characteristics of the treatment and comparison groups, or $E[(\varepsilon_{h1} - \varepsilon_{h0})(X_{h1} - X_{h0})] = 0$.

Difference in differences estimates control for time-invariant fixed effects by differencing them out of the estimates. However, there are potentially several sources of unaccounted bias. The first source of bias could be the result of the effects of program interventions on the comparison group. Because the original sample is composed of 10 villages within the same district, effects of the irrigation investment may "rub off" on the control group. This would diminish the impact estimate constructed by making comparisons between control and treatment groups. However, due to the relatively large distances between villages and the paucity of public or private transportation, these effects are likely to be small at best. Four out of 10 villages in the original study are located on the opposite sides of the Niger River, so a physical barrier inhibits easy interaction between villages. The second source of bias is due to possible selection bias. If initial conditions that influence village- and household-level welfare are correlated with the selection criteria for program participation, biased impact assessments will result. In our case, access to irrigation is strongly predicated by access to the Niger River. Villages that have access to the Niger may have more commercial activities and lower transportation costs, which would increase their purchasing power. While difference in differences estimates do not completely control for this selection bias, using propensity score matching or propensity score matching along with the difference in differences estimates can control for the correlation between observable factors influencing household welfare and program participation.

Propensity Score Matching

To estimate the effects of irrigation, propensity scores are used to match households with similar observable characteristics, varying only the treatment, which is access to irrigation. Households are matched to each other conditional on a set of observable household and village characteristics, *Z* and *V*, respectively. Propensity scores are estimated to match households with similar observable characteristics, varying only the treatment—access to irrigation. The following probit model is estimated using a vector of household characteristics, *Z* and village characteristics, *V*, to obtain predictions of household propensity scores, where:

$$P^{*}_{v,h} = \beta Z_{v,h} + \gamma V_{v,h} + \varepsilon_{v,h}\,, \tag{5.13}$$

where $P_{v,h} = 1$, if $P^{*}_{v,h} > 0$ (5.14)

$= 0$ otherwise.

Then the distribution of $P_{v\,h,,}$ given $Z_{v\,h}$, $V_{v,h,,}$ yields the familiar result:

$$P(P_{v,h} = 1 \mid Z_{v,h}, V_{v,h}) = P(P^{*}_{v,h} > 0 \mid Z_{v,h}, V_{v,h})$$

$$= P(\varepsilon_{v,h} > -\beta Z_{v,h} - \gamma V_{v,h} \mid Z_{v,h}, V_{v,h})$$

$$= 1 - \Phi(-\beta Z_{v,h} - \gamma V_{v,h}) = \Phi(\beta Z_{v,h} + \gamma V_{v,h})$$

$$=1-\Phi(-\beta Z_{v,h} - \gamma V_{v,h}), \qquad (5.15)$$

where Φ(.) is the standard normal cumulative distribution function.

To estimate equation (5.13), household variables are used as controls, including household size, household assets such as household durables and total livestock units, the age of the household head, an education indicator for the household head and his or her spouse, an ethnicity indicator variable, and landholdings. Village characteristics include indicators for distance to the nearest road, distance to the Niger River, and the log price for transporting a sack of rice to Mopti, a regional center. These characteristics control for village development; access to water, which is a necessary precondition for pump agriculture, given the dearth of rainfall; and market integration. When the propensity score matching estimates are generated, the sample is also restricted to matches within villages, so that intervillage fixed effects do not bias the estimates. Table 5.5 displays the descriptive statistics for the household and village characteristics.

Table 5.5: Household descriptive statistics for propensity matching

Household Characteristics		Education of Head (1 if yes)	0.11
Access to Irrigation	0.23		(0.31)
	(0.42)	Education of Spouse (1 if yes)	0.07
Age of Household head*	3.86		(0.26)
	(0.69)	***Ethnicity***	
Household Durables*	11.1	Peulh (1 if yes)	0.18
	(1)		(0.38)
Total Livestock Units	3.05	***Village Characteristics***	
	(5.69)	Road through Village	0.26
Land (Hectares)	2.18		(0.44)
	(2.80)	Road between 1-10kms	0.45
Land Squared (Hectares)	9.23		(0.50)
	(22.81)	River Access	0.31
Household size*	1.40		(0.46)
	(0.50)	Rice Transport Price to Mopti	2152.66
			(568.37)

Notes: N=242. Numbers in parentheses are standard deviations. Mopti is the nearest urban area.
* denotes the natural logarithm of a variable was taken and used for analysis.

These variables are used in the specification to generate the propensity scores that should satisfy the balancing property. That is, the treatment and comparison observations are tested to ensure equality of observables across different propensity score groupings, so that there is an appropriate distribution of characteristics in each grouping of propensity scores. The assumption that $0 < P(T=1 \mid Z) < 1$ is satisfied in our sample and the top and bottom 5 percent of the sample have been trimmed, following Smith and Todd (2005). Figure 5.4 illustrates the region of common support from the density estimates of the propensity scores by treatment status.

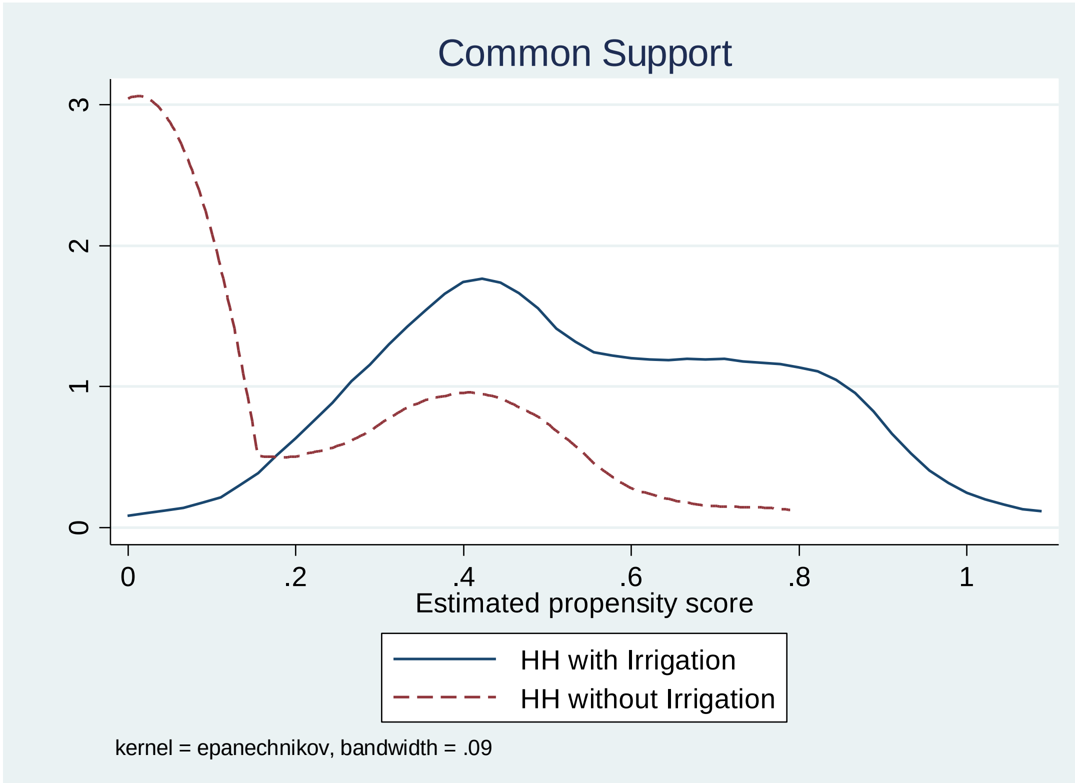


Figure 5.4: Distribution of propensity scores for households with irrigation and without irrigation

Four matching estimators are employed as robustness checks. These estimators include a single nearest-neighbor matching estimator with replacement, a nearest-neighbor estimator using the 10 nearest neighbors with replacement, an Epanechnikov kernel-matching estimator, and a local linear matching estimator. Both nearest-neighbor matching estimators are constructed with replacement of observations after they are matched. Replacement increases the quality of the matches by using more information to construct the counterfactual, but it increases the variance of the estimator by reducing the number of nonparticipant observations used in the comparison group. A nearest-neighbor estimator using 10 nearest neighbors with replacement increases the quality of matches but with the tradeoff that the variance of the estimator is increased.

The third estimator employed is the Epanechnikov kernel-matching estimator for the average treatment effect on the treated, which is constructed such that:

$$ATT = \frac{1}{n}\sum_{i\in T}[Y_t^{1} - \frac{\sum_{j\in C} Y_j^{0} K(\frac{P_j(Z)-P_i(Z)}{a_n})}{\sum_{k\in C} K(\frac{P_k(Z)-P_i(Z)}{a_n})}], \qquad (5.16)$$

where T is the treatment group, K is the kernel function, C is the comparison group, and a_n is the band-width parameter proposed in Heckman, Ichimura, and Todd (1997) and Heckman et al. (1998).

The last estimator is the local linear matching estimator, which is a generalized version of the kernel estimator. The advantage of the local linear matching estimator is that it is generally more robust to data design densities and has a faster rate of convergence at the boundary points (Smith and Todd 2005). These four estimators are used here to generate propensity score estimators, but they will also be used in the next section as a robustness check with the difference-in-differences matching estimator.

Difference-in-Differences Matching Estimator

The last econometric strategy to evaluate the impact of irrigation is a difference-in-differences matching estimator. Let the outcome variable of interest (agricultural production, consumption, nutrient intake, or dietary diversity) be represented by Y_{ht} for household $h=1,\ldots, N$ at time $t=1, 2$. Then variation in Y_{ht} is explained by covariates X_{ht} for household h at time t. The treatment variable, T indicates the household's access to irrigation. P is the propensity score estimated as in the above section using the probit model. In a pooled cross section,

$$Y_{ht} = \beta X_{ht} + \lambda T + \gamma P + \varepsilon_{ht}, \tag{5.17}$$

where the error term represents an idiosyncratic (ε_{ht}) error term. Because selection bias due to the correlation of program placement with household characteristics (assets, education, location, etc.) is probable, the inclusion of the propensity score controls for the selection bias of the observable characteristics when the impact of irrigation is estimated on the outcome variables. Using the predicted propensity scores and taking first differences with the panel subsample yields the difference-in-differences matching estimator, γ^{m}.

$$Y_{h2} - Y_{h1} = \beta(X_{h2} - X_{h1}) + \gamma^{m} T + \gamma P + (\varepsilon_{h2} - \varepsilon_{h1}). \tag{5.18}$$

To provide estimates of irrigation's impact that do not necessarily depend on the estimator chosen, the results of nearest-neighbor estimates with the closest neighbor, nearest-neighbor estimates with the 10 closest neighbors, the Epanechnikov kernel estimator, and the local linear matching estimator are all reported as robustness checks. These estimators were described above. All standard errors of the estimator are bootstrapped with 1,000 repetitions. In the next section, the results of these three different econometric techniques to account for selection bias and endogenous program placement are presented.

V. Empirical Results

Impact Estimates using Difference-in Differences and Propensity Score Matching

In the difference-in-differences results (Table 5.6), the consumption aggregates for the control group are higher than those of the irrigation group were before most of them actually had access to the irrigation intervention. This may be because irrigation interventions were targeted initially to relatively poor villages. The difference-in-differences estimate between groups is 148,529 FCFA or almost US$300. Increases in the consumption aggregate of the irrigation group are significant at the 1 percent level. Agricultural production by households with access to irrigation has increased more than threefold over the past eight years, compared with farmers who do not have irrigation. Agricultural production for the control group declines slightly. Increases in the irrigation group are significant at the 1 percent level. The difference-in-differences estimate suggests a 1.9-ton increase for households who have access to irrigation.

Table 5.6: Difference-in-Differences Results

	1998			2006			Differences 1998-2006	
Variable	N	Mean	SD	N	Mean	SD		
Consumption Aggregate (Real FCFAs)	227	482,729	346558	246	541,155	294,436	65,225	**
With irrigation	81	427,961	343826	82	589,107	299,357	160,755	***
Without Irrigation	146	513,114	345494	164	517,178	289,891	12,226	
Difference with and without irrigation		-85,152			71,929		148,529	***
Agricultural Production (kg)	246	447.1	879.1	246	1,028.2	1,554.6	581.0	***
With Irrigation	82	589.9	958.5	82	2,472.5	1,845.2	1,882.6	***
Without Irrigation	164	375.7	830.5	164	306.0	605.2	-69.7	
Difference with and without irrigation		214.3			2,166.5		1,952.3	***
Daily Household Calories	228	5,307.4	301.0	228	5,096.9	208.4	-210.5	
With irrigation	59	4,398.1	387.0	59	6,234.8	474.8	1,836.8	***
Without irrigation	169	5,624.9	380.5	169	4,699.7	220.0	-925.2	***
Difference with and without irrigation		-1,226.8			1,535.1		2,762	**
Daily Household Protein (grams)	228	160.5	8.9	228	139.3	5.7	-21.1	***
With irrigation	59	136.0	11.4	59	172.4	13.1	36.4	***
Without irrigation	169	169.0	11.3	169	127.8	6.0	-41.2	***
Difference in protein with and without irrigation		-33.1			44.6		77.6	***

Notes: *significant at 10% level. ** significant at 5% level. *** significant at 1% level.

Calorie and protein intakes per day between households with and without access to irrigation are also displayed in Table 5.6. These results can be compared with the recommended dietary allowances of the Food and Nutrition Board of the National Academies, which recommends a daily caloric intake of 2,500 calories and protein intake of 392 grams per day for active adult males (Otten et al. 2006). Households with access to irrigation have increased their daily caloric intake by 1,836 calories, whereas households without irrigation have decreased their daily caloric intake by 925 calories. Statistically significant increases in protein intakes are also found in households who have access to irrigation. The difference-in-differences estimate is 77.6 grams of additional daily protein intake per household. Despite statistically significant increases in both calories and protein, households with irrigation still fall 18,000 calories below what would be required for the mean household of six in the sample, according to the recommended dietary allowances.

Table 5.7 presents the results of the probit model used to estimate the propensity scores given village and household characteristics. Significant characteristics that predict access to irrigation include infrastructure such as roads and access to the Niger River. However, this is not a causal model. The specification chosen satisfies the balancing property and does not include all observable household characteristics from the data set that could possibly influence irrigation access. The use of the balancing property to include variables as part of the propensity score specification ensures that a comparison group is constructed with observable characteristics distributed equivalently across quintiles in both the treatment and comparison groups, as described by Smith and Todd (2005).

Table 5.7: Probit model results

	Irrigation
HH Characteristics	
Ln Age of Household head	-0.026
	(0.130)
Ln Household Durables	0.012
	(0.145)
Total Livestock Units	-0.047
	(0.035)
Land (Hectares)	-0.343
	(0.318)
Land Squared (Hectares)	0.078
	(0.071)

Table 5.7 (Continued)

	Irrigation
Ln Household size	-0.17
	(0.282)
Education of Head (1 if yes)	0.114
	(0.437)
Education of Spouse (1 if yes)	0.08
	(0.486)
Ethnicity	
Peulh (1 if yes)	-0.551
	(0.504)
Village Characteristics	
Road through Village	14.168
	(2.334)***
Road within 10kms	0.648
	(0.679)
River Access	14.6
	(1.964)***
Rice Transport Price to Mopti	0
	(0.001)

Notes: N=212. Constant is included. Mopti is the nearest urban area. *** Significant at the 1 percent level.

Table 5.8 reports the estimates of the four matching estimators specified for consumption, agricultural production, and nutrient intakes.[43] The results indicate significant effects when either propensity score matching or the difference-in-differences estimator are calculated. However, the magnitudes of the effects estimated with propensity score matching are larger than the difference-in-differences estimates. Consumption is significant at the 1 and 5 percent levels across the different matching estimators. The effect of irrigation on the household total consumption aggregate varies from 734,908 to 776,748 FCFA, depending on the estimator used. Total agricultural production, total daily caloric intakes, and total daily protein intakes are significant at the 1 and 5 percent levels. The effect of irrigation on total agricultural

[43] The Stata command psmatch2 developed by Leuven and Sianesi (2003) is used to estimate the treatment effects in the empirical section.

production ranges from 1.25 to 1.83 tons per household. Increases in calories and protein per week are also statistically significant.

Table 5.8: Average treatment effects on the treated estimates using four different propensity score matching estimators

Estimator	N	Nearest-Neighbor Matching (1)	Nearest-Neighbor Matching (10)	Kernel Epanechnikov	Local Linear Matching Estimator
Outcome Variables					
Household Consumption (FCFA)	98	775,674	734,908	776,748	775,673
		(339,480)**	(270,311)***	(278,568)***	(320,187)**
Agricultural Production (kg)	98	1,254	1,647	1,361	1,835
		(351)***	(276)***	(341)***	(292)***
Daily Total Household Calories	98	8,428	9,205	9,796	8,429
		(3,596)**	(2,916)***	(3,194)***	(3,697)**
Daily Total Household Protein	98	228	281	299	228
		(114)**	(89)***	(99)***	(108)**
Household Composition					
Men	98	.78	.906	.862	.776
		(.530)	(.420)**	(.424)**	(0.517)
Women	98	.286	-.178	.041	.286
		(0.578)	(0.434)	(0.475)	(0.562)
Boys	98	-.510	-.361	-.405	-.510
		(0.491)	(0.340)	(0.375)	(0.497)
Girls	98	0	-.337	-.082	0
		(0.536)	(0.436)	(0.469)	(0.560)
Informal Food Sharing					
Meals Given to other HH	98	.367	.690	.756	.367
		(.475)	(0.363)*	(.390)*	(.487)
Meals Received from other HH	98	-1.449	-.527	-.443	-1.449
		(1.611)	(1.291)	(1.086)	(1.545)
Net Sharing Indicator	98	.224	.204	.213	.224
(1 if HH gives more meals than received)		(.087)**	(.076)***	(.079)***	(.085)***
Livestock (in Total Livestock Units)	98	6.4	6.3	5.8	6.4
		(2.19)***	(2.323)***	(2.05)***	(2.321)***

Table 5.8 (Continued)

Estimator	N	Nearest-Neighbor Matching (1)	Nearest-Neighbor Matching (10)	Kernel Epanechnikov	Local Linear Matching Estimator
Children's Weekly School Hours	137	-12.4	-2.33	-1.014	-10.73
	(children)	(6.68)*	(4.003)	(5.22)	(6.443)*
Children's Weekly Farm Work Hours	137	7.15	4.42	6.82	3.36
	(children)	(5.26)	(4.657)	(4.207)	(4.86)

Note: All standard errors are bootstrapped with 1,000 repetitions. * Significant at the 10% level, ** significant at the 5% level.

Lastly, the matched difference-in-differences estimator, using propensity scores to control for the endogeneity of access to irrigation, is estimated in Table 5.9, which presents the average treatment effects on the treated. The difference-in-differences matching estimates indicate that the impact of irrigation on consumption ranges from 694,921 to 739,050 FCFA. Estimates of the impact of irrigation on agricultural production range from 1.17 to 1.89 tons per household. The impact of total household calories and protein intakes per week are also statistically significant across the matching estimators, although the matched difference-in-differences estimates are greater across all estimators. The propensity score matching estimates and matched difference in differences are similar, despite variations in the estimators and evaluation techniques.

Table 5.9: Difference-in-differences matching

Differences in the Outcome Variables (1998-2006)	N	Nearest Neighbor Matching (1)	Nearest Neighbor Matching (10)	Kernel Epanechnikov	Local Linear Matching Estimator
Household Consumption (FCFA)	98	738,148	694,921	739,050	738,148
		(310093)**	(274,938)**	(292275)**	(318,645)**
Agricultural Production (kg)	98	1,170	1,591	1,284	1,888
		(367)***	(288)***	(341)***	(295)***
Daily Total Household Calories	98	11,371	10,494	10,618	11,371
		(4862)**	(3,742)***	(4,230)**	(4,611)**
Daily Total Household Protein	98	360	326	328	361
		(141)**	(115)***	(126)**	(144)**
Livestock (in Total Livestock Units)	98	6.6	6.4	6.2	6.6
		(2.13)***	(2.07)***	(2.03)***	(2.19)***
Household Composition					
Men	98	.429	.733	.625	.429
		(.483)	(.364)**	(.370)*	(.444)**
Women	98	.265	-.139	.106	.265
		(.585)	(.449)	(.514)	(.601)
Boys	98	-.326	-.237	-.073	-.327
		(.548)	(.411)	(.439)	(.550)
Girls	98	-.061	-.112	.187	-.061
		(.587)	(.438)	(.471)	(.605)

Note: All standard errors are bootstrapped with 1,000 repetitions. * Significant at the 10% level, ** significant at the 5% level.

Differences in the Impact of Irrigation on Household Agricultural Production and Consumption

Despite the robust response of the estimates to different estimators on the impact of irrigation on household agricultural production and total consumption, the benefits of agricultural production induced by irrigation technology do not transfer one-to-one into gains in household consumption. The lack of unity between production and consumption potentially presents a problem in establishing irrigation’s impact on poverty reduction, because gains in agricultural production could be offset by higher input costs, which erode the benefits of irrigation technology and are reflected in lower household consumption.

There are two hypotheses that could explain this pattern in the data. Consuming the gains from increased agricultural production from irrigation may not be the only household strategy for increasing welfare. Households could also save these gains or share some of them with others in their village, either for purely altruistic reasons or as an informal kind of intravillage insurance against future shocks. Empirical evidence for the saving hypothesis is found in other studies. Ravallion and Chen (2005) found that antipoverty programs in southwest China had little impact on consumption but a large impact on household saving, because the community expected that the program's duration would be short.

To test the hypotheses of increased savings or increased intravillage sharing, the estimates of a standardized asset, livestock, reported in total livestock units (TLUs) and the number of meals shared and received are estimated using propensity score matching. The evaluation estimators support both hypotheses: saving via livestock accumulation and sharing of meals both increased. Irrigation significantly increases livestock holdings by 5.8 to 6.4 TLUs using propensity score matching and 6.2 to 6.6 TLUs with matched difference in differences (Table 5.8). Meals given to other households significantly increase by 0.69 to 0.76 meals per week, while the number of meals received did not change with any statistical significance (Table 5.9). According to a net sharing indicator that represents 1 if the household is a net sharer, or 0 if the household receives more meals than it gives, households were 20.0–22.4 percent more likely to be net sharers if they had access to irrigation.

In addition to these variables, the number of hours children spend in school and on farm work and changes in household composition are evaluated as outcome variables, using propensity score matching in Table 5.8. Child labor could plausibly increase with the introduction of irrigation technology because the demand for household labor will increase as the household responds to more lucrative income opportunities, which increase the opportunity costs of children's time. While there was no effect on the hours children spent on farming, hours spent on schooling did decrease in households with access to irrigation by 10.7 to 12.4 hours per week in two of the estimators used. Decreased hours of schooling have potentially serious long-term implications for human capital accumulation. Another outcome variable that may erode the effects of increased agricultural production on household consumption is household composition changes that increase household size in response to the increased labor demands that irrigated agriculture necessitates. In Table 5.8, the propensity score matching estimates illustrate that in households with access to irrigation, the number of men in the household increased by almost one additional member, while there was no effect on the number of women, boys, or girls.

VI. Conclusions

Regardless of the estimation method used to evaluate irrigation investments in northern Mali, significant positive increases in total household consumption, agricultural production, and caloric and protein intakes are estimated for households who have access to irrigation. These results reinforce previous studies on smallholder irrigation investments by showing that, in an area with low agricultural potential, welfare gains can be realized with targeted investment (Lipton, Litchfield, and Faurès 2003; Hussain 2007b). Irrigation investment also induces households to save more and share more within their villages, which is a type of investment in informal social insurance. Both of these responses to irrigation are effects not captured by estimating program effects using consumption aggregates.

In future work, a major interest will be to investigate the role that village-level investments in irrigation have in reducing inequality within villages and households. Because irrigation interventions are primarily targeted at the village level in northern Mali, this may promote greater reductions in poverty and inequality than larger-scale projects that are primarily targeted to larger urban population centers. Because male and female expenditure data were collected, investigating the impact of irrigation on intrahousehold inequality may also yield important insights into household behavior. Differences in welfare gains between genders may be of particular concern because most irrigation projects are targeted to men. If irrigated plots require more labor, then women may be drawn away from their plots to work on irrigated plots, for which they do not control the output.

This paper provides direct evidence about the returns to irrigation by tracking households from 10 villages over an eight-year period. Small-scale irrigation projects can have significant impacts on household consumption, agricultural production, and nutrition. In an environment such as northern Mali, where the Sahelian droughts have been severe and agro-ecological conditions are not favorable to rain-fed agriculture, a green revolution is possible if villages harness the water provided by the Niger River. Not only do irrigation projects increase village food supply, but they also reinforce informal sharing within villages and help households build assets that may serve to buffer consumption against transitory income fluctuations, particularly during the lean season. These secondary effects of irrigation projects can be overlooked if net benefits of irrigation projects are only evaluated with respect to household consumption.

CHAPTER 6: CONCLUSION

Understanding how households make labor allocation decisions and schooling choices for children is a critical intertemporal choice for households where reductions in income today from allocating children to non-renumerative activities such as school or leisure are offset by the discounted value of the child's future earnings. This dissertation presents two papers which address the participation of children and their distribution of time in market activities, domestic activities, and schooling. The last paper investigates whether village irrigation investments by international organizations have durable impacts on household level outcomes including consumption, agricultural production, and nutrition, as well as the household's asset accumulation and informal sharing networks between irrigators and non-irrigators. These labor allocation and production decisions are arguably the two most critical decisions that households face in northern Mali through which a better understanding by development economists and policy makers will enable their application to influence long term economic development.

While there is an extensive literature on child labor and schooling individually, there has been less but increasing attention to examining explicitly the joint determination of children's time including both schooling and various forms of child labor. Chapters 3 and 4 also examine the magnitudes of changes in the probabilities that children work and the changes in the hours of work that children do, conditional on working, in response to production and health shocks. They also investigate whether and which type of assets mitigate the effects of shocks on increasing child labor and preventing children from being withdrawn from school which is critical to the design of development interventions. If assets do mitigate much of the increased risk of children to increased work in response to unexpected shocks, then one would expect that policies that increase macroeconomic stability and the development of financial markets would be a critical component of protecting children from the vagaries of unexpected covariate and idiosyncratic shocks. However, if assets have a mixed role in protecting children from being withdrawn from school and increasing their participation or hours of work, then understanding children's labor substitutions patterns within households which depend on parent, child, household, and village characteristics are essential to the design of effective social protection programs.

Evidence from chapter 3 illustrates these points. Production shocks from harvest period pest infestations induce households to withdraw children from school and increase the probability that they are selected into farm work. Health shocks to women increases the probability that a child participates in the family business and childcare activities. These results are robust to varying assumptions about the structure of unobserved heterogeneity at the household and village levels. Different measures of household assets are also constructed to test whether assets serve as a buffer against increased child labor in response to shocks. Assets such as livestock have mixed effects on child labor and schooling, depending on the shock and asset type. However, household durables are substitutes for increased child labor when households face health shocks.

Chapter 4 uses hours data from the same activities considered in chapter 3 to compare the effect of household, individual, village and district characteristics on labor supply and hours in school. These data are considered in the same robust framework where household random effects and cross-equation correlations are allowed as verification across different specification of the consistency of the results. In addition a subjective survey module where children report the relative distribution of their time is included in the analysis as a comparison with the hours data.

Lastly, Chapter 5 investigated the role that access to irrigation has on household welfare, agricultural production and nutrition. Significant changes in the agricultural sector in northern Mali suggest a large contribution of irrigation to welfare increases over the past 8 years. Using difference in differences, propensity score matching and matched difference in differences, the impact of access to irrigation on household consumption, production, and nutrient intakes is estimated. Though the net benefit ratios calculated from household consumption range from 1.5-1.6, differences between the agricultural production and consumption treatment effects suggest that gains in agricultural production value do not transfer uniquely to household consumption. Two alternative hypotheses are tested; that the gains in agricultural production induced by irrigation yield higher household saving or intra-village transfers from irrigators to non-irrigators contribute to informal social insurance. Chapter 5 provides evidence of both saving and sharing within villages as an alternative strategy to consuming gains in agricultural production. This finding suggests that estimating program impact using consumption per capita may underestimate the welfare gains of irrigation investment by ignoring the household’s saving and informal insurance network.

APPENDICES

Appendix 1: Questionnaire Organization

Community Characteristics

1. Meta-data
2. Health
3. Migration
4. School
5. Infrastructure
6. Agriculture
7. Physical and Demographic Characteristics

Household Questionnaires

Women's Questionnaires

1. Household Information
2. Possessions
3. Agricultural Exploitation
4. Herding
5. Non-Agricultural Revenue
6. Non-Food Expenditures
7. Credit/Savings
8. Food Consumption (together with HH Head)
9. Food Security Survival Strategies
10. Women's Time Allocation

Men's Questionnaires

1. Household Information
2. Household Composition (with female respondent)
3. Household Education
4. Household Activities
5. History of Household
6. Migration
7. Agricultural Exploitation
8. Herding
9. Fishing
11. Non-Agricultural Revenue
12. Non-Food Expenses
13. Credit/Savings
14. Men's Time Allocation
15. Economic Shocks

Children's Questionnaires

1. Child Work
2. Education
3. Child Health
4. Anthropometry

Appendix 2: Sample Decomposition

Cercle	Number of Communes Represented	Number of Rural PSUs	Number of Urban PSUs	HH Selected
Niafunke	8	55	2	819
Goundam	7	21	5	455
Dire	10	23	2	243
Tombouctou	5	14	1	272
Rharous	4	10	1	85
Bourem	3	16	2	294
Kidal	1	0	1	13

Appendix 3: Definitions of Variables

Variable	Definition
Chapter 3	
School Participation	1 if child attended school during the last school year; 0 otherwise
Farm Participation	1 if the child engaged in farming during the school year; 0 otherwise
Family Business Participation	1 if the child engaged in the family business during the school year; 0 otherwise
Childcare Participation	1 if the child engaged in caring for other children of the household during the last school year; 0 otherwise
Market Production and School Participation	1 if the child attended school and participated in either farmwork or the family business; 0 otherwise
Home Production and School Participation	1 if the child attended school and participated in child care; 0 otherwise
Market and Home Production Participation	1 if the child participated in either farm work or the family business and childcare; 0 otherwise
Withdrawn from School	1 if the child was withdrawn from school during the past academic year given that they had been enrolled previously; 0 otherwise
Child Characteristics	
Boy Indicator	1 if a boy; 0 otherwise
Age Indicator for ages 11-17	An Indicator was created for each age 11-17 which was 1 if the child was a given age
Ethnicity	by ethnic group; an indicator is included for each ethnic group except the most populous ethnic group
Household Composition	
Biological child indicator	1 if the child is the biological child of parents that reside in the household; 0 otherwise
Number of girls	Number of girls aged 0-17 years old in the household
Number of boys	Number of boys aged 0-17 years old in the household
Number of adult men	Number of adult men aged 18 or older in the household
Number of adult women	Number of adult women aged 18 or older in the household

Household Assets and Unearned Income	
Livestock Value (FCFA)	the value of livestock owned by both men and women in the household in FCFA
Herd Size (Number of Animals)	the number of animals owned by both men and women in the household
Agricultural Capital (FCFA)	the value of agricultural capital owned by the household in FCFA
Household Durables (FCFA)	The value of durable assets owned by the household in FCFA
Migrant Remittances (FCFA)	the value of migrant remittances received by the household over the past 4 months in FCFA
Parental Characteristics	
Any Mother's Education	1 if the child's mother has any education; 0 otherwise
Any Father's Education	1 if the child's father has any education; 0 otherwise
Age of HH Head	Age of the household head indicated from the household roster
Age of HH Head's spouse	Age of the household head's spouse indicated from the household roster
Community Characteristics	
Access to River	1 if the village has access (within 5 km) of the Niger River; 0 otherwise
Roads	
within 1-10km	1 if the village is within 1-10km of a road; 0 otherwise
within 11-20km	1 if the village is within 11-20 km of a road; 0 otherwise
greater than 20km	1 if the village is farther than 20km from a road; 0 otherwise
School Characteristics	
Primary School in Village	1 if the village has a primary school in the village proper; 0 otherwise
Primary School within 1-5km	1 if the village is within 1-5 km of a primary school in another village; 0 otherwise
Primary School farther than 5km	1 if the village is farther than 5km from a primary school; 0 otherwise
Multiple Primary Schools	1 if the village has more than one primary school; 0 otherwise

Student-Teacher Ratio	The student to teacher ratio reported from interviewing school principals from the Community Questionnaire
Repetition Rate	The Repetition rate in the child's school as reported in the Community Questionnaire
Exam Pass Rate-Boys	The Final 6th grade or 9th grade exam pass rate for boys as reported by the school principal in the Community Questionnaire
Exam Pass Rate-Girls	The final 6th grade or 9th grade exam pass rate for girls as reported by the school principal in the Community Questionnaire
Secondary School in Village	1 if there is a secondary school in the village; 0 otherwise
High School in Village	1 if there is a high school in the village; 0 otherwise
Shocks	
Large Crop Loss	1 if the household reported a large crop loss on any of its plots over the previous agricultural season; 0 otherwise
Small Crop Loss	1 if the household reported a small crop loss on any of its plots over the previous agricultural season; 0 otherwise
Adult Male Sick	1 if any adult male was sick in the household in the past month such that they were unable to work; 0 otherwise
Adult Female Sick	1 if any adult female was sick in the household in the past month such that they were unable to work; 0 otherwise
Child Sick	1 if any child was sick in the household in the past month such that they were unable to work; 0 otherwise

Chapter 4

Hours

School	The number of hours the child normally spends in school during the school year
Farm	The number of hours the child normally spends doing farm work during the school year
Family Business	The number of hours the child normally spends doing work in the family business during the school year
Chores	The number of hours the child spends doing chores and domestic work during the school year

Child Care	The number of hours the child spends caring for other children in the household during the school year
Market Work	The number of hours the child spends doing farm work and working in the family business during the school year
Domestic Work	The number of hours the child spends caring for other children and doing household chores in the household during the school year
Total Work	The total number of hours the child spends doing market and domestic work during the school year
Subjective Measures	
School	The number of school (red) cardboard papers out of 10 total papers the child selects to represent the proportion of their week that they spend in school
Work	The number work (yellow) cardboard papers out of 10 total papers the child selects to represent the proportion of their week that they spend in working

Ch. 5

HH Characteristics	
Ln Age of HH head	log of the age of the household head
Ln HH Durables	log of the household's durable stock
Land (Hectares)	Number of hectares of land cultivated by the household
Land Squared (Hectares)	The number of hectares squared that the household cultivates
Ln HH size	log of the household size
Education of Head (1 if yes)	1 if the household head has any education; 0 otherwise
Education of Spouse (1 if yes)	1 if the household head has any education; 0 otherwise
Ethnicity	
Peulh (1 if yes)	1 if the head of household is of Peulh ethnicity

Household Consumption (FCFA)	Total household consumption calculated for one year from weekly food expenditures, non-food expenditures and assets. Quantities of purchased food, food received from other households and own consumption were valued at village median prices calculated from the survey data. Assets were assumed to have an annualized value of 20% of their current value.
Agricultural Production (kg)	Total household agricultural production per hectare from men's and women's plots
Daily Total Household Calories	Daily total household calories imputed from the food quantities reported in the consumption module. Calories associated with the quantities were the total edible portion of matched food items to the USDA National Nutrition Database
Daily Total Household Protein	Daily total household protein imputed from the food quantities reported in the consumption module. Calories associated with the quantities were the total edible portion of matched food items to the USDA National Nutrition Database
Informal Food Sharing	
Meals Given to other HH	Number of meals that are given by the household to other households in the previous week
Meals Received from other HH	Number of meals that are received by the household from other households in the previous week
Net Sharing Indicator	1 if HH gives more meals than received from other households; 0 otherwise
Livestock (in Total Livestock Units)	The number of animals was scaled by a conversion factor to be equal to a Tropical Livestock Unit. 1 cattle = 1 TLU 1 goat== .15 TLU 1 Horse= 1 TLU 1 Mule= 1.15 TLU 1 Donkey= .65 TLU 1 camel = 1.45 TLU 1 poultry = .005 TLU

Appendix 4: Child Labor Model

To summarize the household's problem, the parents must choose the following variables for the respective period:

Period 1: n.

Period 2: $c_2,\ T_A^{\ F}, T_A^{\ H}, T_C^{\ F}, T_C^{\ H}, T_C^{\ S}, s, k$.

The household's problem can be reduced in complexity by substitution of the home and market production equations (3.4 and 3.5) into the second period budget constraint. Equations 3.2 and 3.3 can be substituted into the monotonically increasing utility function as it will bind at the optimum. The cognitive skills production function (Equation 3.7) can be substituted in Equation 3.6, the period 3 income of the child, which can directly replace its argument in the utility function. After these substitutions, the household's problem reduces to a three equation system with a utility function and two time constraints (adult and child):

MAX

$$u[p\delta q(T_A^{\ F}, T_C^{\ F} \mid K, L) - w_A^{\ F} T_A^{\ F} - w_C^{\ F} T_C^{\ F} + h(T_A^{\ H}, T_C^{\ H}) - w_A^{\ H} T_A^{\ H} - w_C^{\ H} T_C^{\ H} + w_A^{\ W} T_A^{\ W} - (b + c_1 + s)n - k, rk] + \beta n U^*(c_2, y_3(c_2, E))]$$

$$\{c_2, T_A^{\ F}, T_A^{\ H}, T_A^{\ W}, T_C^{\ F}, T_C^{\ H}, T_C^{\ S}, k\}$$

s.t. , (A.1)

$$T_C \equiv T_C^{\ F} + T_C^{\ H} + T_C^{\ S} + T_C^{\ L}, \tag{A.2}$$

$$T_A \equiv T_A^{\ F} + T_A^{\ H} + T_A^{\ W} + T_A^{\ L}\ . \tag{A.3}$$

The Lagrangian function can be written as follows after which the first order conditions are as follows:

$$£ = U + \lambda_1\ (T_C - T_C{}^F - T_C{}^H - T_C{}^S - T_C{}^L) + \lambda_2 (T_A - T_A{}^F - T_A{}^H - T_A{}^L)\,, \tag{A.4}$$

FOC (if $\lambda_1, \lambda_2 > 0$),

$$\text{n:} \qquad \beta U^*(c_2, y_3) = \frac{\partial u}{\partial a_2}\ (b + c_1 + s)\,, \tag{A.5}$$

$$\text{s:} \qquad \beta \frac{\partial U^*}{\partial y_3} \frac{\partial y_3}{\partial E} \theta f'(Q,s) g(T_C{}^S) = \frac{\partial u}{\partial a_2}\ , \tag{A.6}$$

$$T_C{}^S: \qquad \beta n \frac{\partial U^*}{\partial y_3} \frac{\partial y_3}{\partial E} \theta f(Q,s) g'(T_C{}^S) = \lambda_1\ , \tag{A.7}$$

$$T_C{}^H: \qquad \frac{\partial u}{\partial a_2} [\ h'(T_A{}^H, T_C{}^H) - w_C{}^H\ ] = \lambda_1\,, \tag{A.8}$$

$$T_C{}^F: \qquad \frac{\partial u}{\partial a_2} [\ p\delta q'(T_A{}^F, T_C{}^F) - w_C{}^F\ ] = \lambda_1\,, \tag{A.9}$$

$$\text{k:} \qquad \frac{\partial u}{\partial a_2} = \frac{\partial u}{\partial a_3} r\,. \tag{A.10}$$

Equations A.5 - A.11 characterize the allocation of the household's optimal number of children, the distribution of adult and child time across activities, the child's period 2 consumption and the allocation of assets for period 3 adult consumption. The household's decisions are examined given these first order conditions, including the optimal number of children and child participation in schooling, domestic production, and market production.

Fertility Conditions

Rearranging Equation A.5 yields the condition by which the household chooses its optimal number of children, n*. For each additional child, the income equivalent of an additional child is equated to the marginal cost of the child. The cost of each additional child includes period 1 costs, *b*, of the child's birth and early child care costs including medical care, clothes, period 1 consumption, period 2 consumption, and the cost of school if the household elects to send the child.

$$\frac{\beta U^*(c_2, y_3)}{\partial u / \partial a_2} = b + c_1 + s \qquad \text{(A.11)}$$

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