ABSTRACT

WADOOD, SYED NAIMUL. The Impact of Employment Uncertainty in the Off-farm Labor Market on Developing Country Farmers' Crop Choice Decisions. (Under the direction of Dr. Walter N. Thurman and Dr. Russell L. Lamb).

The purpose of this research has been to examine the link between agricultural production decisions, particularly ex ante crop choice decisions, and off-farm labor income opportunities available to the cultivator households in a developing country context. The cultivator households in some areas of the developing countries use off-farm labor supply as an insurance against shocks in crop income. Yet employment is uncertain in the off-farm labor market. This thesis hypothesizes that, given limited opportunities for ex post consumption smoothing, employment uncertainty in the labor market influences risk averse farmers' ex ante crop choice decisions and farmers would opt for more conservative crop choices in case they expect unfavorable supply opportunities in the off-farm labor market at a later period.

A two period stochastic dynamic programming model is developed. It has been shown that under some particular conditions, risk averse farmers' expectations of a lower depth of the labor market or a lower wage rate in that market in the next period would lead them to allocate more land to crops with safer returns. Again, in the presence of some risk-mitigating factors such as irrigation, farmers would take more risks in crop choices. For estimation, a panel data set from the ICRISAT survey of the semi-arid areas of India is used. Fixed effects and random effects Tobit specifications for estimating household land share and fixed effects and random effects specifications for estimating household crop returns and land share differences have been used. The regression results indicate significant impact of household expectation of the harvesting period male unemployment rates in the off-farm labor market

on crop choices, taking the planting period male unemployment rates as a proxy. The results also indicate strong influence of household irrigated land share on crop choices. The results lend weak support for the linkage between crop choice decisions and the share of non-agricultural labor in total labor demand in the off-farm labor market.

THE IMPACT OF EMPLOYMENT UNCERTAINTY IN THE OFF-FARM LABOR MARKET ON DEVELOPING COUNTRY FARMERS' CROP CHOICE DECISIONS

by
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DEDICATION

To

my grandparents

Dr. Moniruzzaman Chowdhury

and

Mrs. Nurunnahar Begum

BIOGRAPHY

I was born in 1972 in Chittagong, Bangladesh. My family moved to Dhaka, the capital city of Bangladesh when I was six. I took Secondary School Certificate examination in 1988 from Motijheel Ideal High School and Higher Secondary Certificate examination in 1990 from Dhaka College. I decided to take economics as major in my undergraduate studies after my higher secondary certificate examination. I began my undergraduate studies at the Department of Economics in University of Dhaka in 1990. I obtained Bachelor of Social Sciences (Honors) degree in 1993 and Master of Social Sciences degree in 1994 from this department. During my final year at the department, I began to concentrate on microeconomics and development economics. I wrote my masters thesis under the supervision of Dr. Nasreen Khundker, an associate professor at my department and the thesis was on a micro-development economics topic. After obtaining my masters degree, I taught undergraduate economics courses at Department of Business Administration in The University of Comilla for one year and a half. I was also involved in research activities at Bangladesh Institute of Development Studies as a part-timer. I began my PhD in Economics at North Carolina State University in 1999. I have returned to my home country, Bangladesh, after defending my final oral examination for the PhD degree. Now I am an Assistant Professor of Economics at the School of Business in Independent University, Bangladesh.

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My parents, Syed Rafiqul Wadood and Khaleda Khanum, and my only sister, Naima Naheed gave me unconditional support and encouragements throughout my graduate school years. Without their love, all these would not have been achieved!

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CHAPTER I

INTRODUCTION

I.A. Background

In the developing countries, risk plays an important role in farmers' production decisions, due to a typically incomplete set of markets in their agricultural sectors. A complete set of markets is important because the competitive equilibrium is considered Pareto-optimal if the set of markets, including insurance markets against risk, is complete (Arrow 1964, Debreu 1959). In this case, there is *separability* between production decisions taken by agricultural households and their risk and consumption preferences (Singh, Squire and Strauss 1986a). In case a complete set of markets does not exist, this *separability* will not hold, and risk considerations will matter in the farm households' production decisions (Antle 1983a, Roe and Graham-Tomasi 1986). In a developing country agricultural sector, many markets (including formal insurance markets) may not even exist, and even if some markets exist, they may function poorly. Therefore risk factors are likely to play a role in farmers' production decisions.

Each season, farmers have to decide the allocation of land under cultivation to different crops. Crop yields differ in their distributions of outcomes. Crops have different fertilizer, irrigation and soil requirements and react differently to weather uncertainty, for example: the date of onset of the monsoon, length of the monsoon, total amount and distribution of rainfall during the monsoon, etc. One may argue that farmers can partly choose the distribution of "crop income" given weather uncertainty and soil conditions by choosing one particular crop over the others, taking into consideration susceptibility of different crops to weather uncertainty, soil and input requirements, etc. In case the household model is nonseparable, in the sense that a household's consumption decisions affect its production decisions, the household may opt for producing more staple crops instead of cash crops to avoid market price risk of the staple crops (Fafchamps 1992a). Also the effect of risk factors involved in crop choice can be more visible among lower income households because they have less wealth to hedge against unforeseen risk (Lamb, mimeo 2002), or they may have less access to credit to secure their current consumption flow from current income shocks (Eswaran and Kotwal 1989).

Apart from crop production, another source of income for the cultivator households is participation in the off-farm labor market. Because of a limited amount of arable land holdings for most farm households, they do not employ all their family labor hours in their own farms. Many times they sell their surplus labor hours on the village off-farm labor market. For example, Kochar (1999) finds that in the two villages of Aurepalle and Kanzara, located in the semi-arid areas of India, 60 to 80 percent of total farm labor was hired labor during 1979-1984. The majority of sample households (70 percent) reported income from the village labor market[1]. These households typically reported two main sources of income: crop income and off-farm labor income. This brings out the possibility that as long as labor market and own-farm productivity are not perfectly correlated, market labor supply can be used as one means for the cultivator households to cope with risk in own-farm crop production (Rose 2001). The off-farm labor market is not without its own aspects of uncertainty -- employment is uncertain in the market at any point of time. To the extent that a major portion of labor hours demanded in this off-farm labor market is agricultural, the same realizations of weather

[1] Household wage income amounted to 25 percent of crop profits on average; while the importance of wage income was much higher among the smaller farmers, with wage income exceeding crop income by 224 percent (Kochar 1999, pp. 51).

conditions play a role in contributing to uncertainty in this market as well, by partly determining wage rates and unemployment rates.

One point that has not yet been directly addressed in the literature to date is the research question of this paper: *does employment uncertainty in the off-farm labor market affect farmers' crop choice decisions?* At the start of the planting period, when farmers decide on their crop choices, uncertainty regarding employment in the off-farm labor market during the rest of the planting as well as the harvesting season is not yet resolved. If farmers expect a robust off-farm labor income during the season, so that they can hedge against any unforeseen shocks in their crop incomes *ex post*, they may show more risk-taking attitudes in their *ex ante* crop choice decisions. For example, they may choose crops with higher expected means but larger expected variances instead of a more conservative set of crops. This probable impact on crop choice decisions can be neutralized or intensified by other factors, including soil requirements, credit constraints, cash income constraints, input fixity, household consumption preferences and correlation between own farm productivity and income earnings from village labor market.

I.B. Motivation

I.B.1. Risk and Risk Responses in Developing Country Agriculture

The two main ways *risk* is manifested in agriculture are *yield risk* and *price risk*. *Yield risk* originates from weather shocks, pest attack, disease and fires. In the semi-arid areas, crop yields are particularly subject to weather risk, since timely rainfall with appropriate quantities at the corresponding stages of the monsoon season is essential for a good harvest.

Risk-averse agricultural households respond to risk in their agricultural crop income in a number of ways. One way to classify their responses is to place them into *ex ante* responses and *ex post* responses. *Ex ante* responses are "the planned, desired or intended level of some activity" while *ex post* responses are "the realized or actual" level -- these two need not coincide (Macmillan 1992, pp. 138). Alderman and Paxson (1992) refer to the *ex post* strategies as "*risk-coping mechanisms*" and Morduch (1995) refers to them as "*consumption smoothing*." The principal pattern of the *ex post* strategies is to stabilize household utility contingent on a realized state-- these strategies are employed after shocks occur and help secure household consumption patterns from fluctuations in income. *Ex post* mechanisms to cope with risk (and smooth consumption) include: (a) use of credit markets (Jodha 1981, Bell 1988, Eswaran and Kotwal 1989, Udry 1995, Kochar 1997a,b); (b) self-accumulation and decumulation of assets such as savings (Deaton 1992, Paxson 1992), bullocks (Rosenzweig and Wolpin 2000), land (Cain 1981) or food storage (Renkow 1990, Saha and Stroud 1994, Park, mimeo 2001); (c) demographic adjustment mechanisms such as reliance on extended family (Kotlikoff and Spivak 1981, Cain 1981), marriage contracts (Rosenzweig and Stark 1989) or remittances (Lucas and Stark 1985, Rosenzweig 1988); and (d) village-level reciprocity in the form of informal insurance contracts (Kimball 1988, Fafchamps 1992b, Coate and Ravallion 1993).

When full markets for *consumption smoothing* do not exist, households can opt for *ex ante* strategies. Alderman and Paxson (1992) refer to these strategies as "*risk-management strategies*" whereas Morduch (1995) refers to them as "*income smoothing*." These strategies are typically in the pattern of taking conservative production or employment decisions before the shock occurs. Households, therefore, take decisions in such a way as to minimize the loss from adverse income shocks, if there is any, before the shock occurs. Morduch presents a list of possible *income smoothing* devices (pp. 109-111). The first include variability-reducing inputs and production techniques; rice farmers in South India have been documented to use more labor than would be called for on grounds of profit maximization alone. In another case, the marginal product of fertilizer use remains 3.5 times its price in Palanpur, Uttar Pradesh, India which shows that farmers are reducing fertilizer investment to reduce possible losses in bad times (Bliss and Stern 1982, pp. 275). The second *income smoothing* strategy is to opt for more conservative mode of production in the face of a riskier production environment (Binswanger and Rosenzweig 1993). The third is that once the household knows that weather will be poor, it may choose to limit production to cut potential losses. As a result, the variability of area cultivated has been found to be higher than yield variability in the ICRISAT study in India (Walker and Ryan 1990, pp. 256). Fourth, the household may opt to delay production decisions unless further useful information on weather conditions is available (Bliss and Stern 1982, pp. 271). Fifth, diversification is another strategy where more vulnerable households (in terms of consumption) devote a greater share of land to safer, traditional varieties of rice and castor than to riskier, high-yielding varieties (Morduch 1990). Sixth, households facing a greater volatility in farm profits are more likely to have a household member employed in steady wage employment (Rosenzweig and Stark 1989), this being the off-farm activity strategy. Seventh, tied labor is another *ex ante* mechanism where a long-term relationship between the employer and the employed ensures a steady but low-wage contract (compared to the wage rates at the daily casual off-farm labor market), a risk-diminishing strategy for both the agents (Bardhan 1983). Eighth, and finally, are labor supply adjustments by which farmers supply more labor *ex ante* in the face of a riskier production environment (Kochar 1999, Rose 2001).

I.B.2. Access to Credit

One important indicator of availability of *ex post* responses to the farmer household is its access to credit. Farmers typically have access to different sources of credit, both formal and informal, but this access can be dependent on household income and wealth. If the farmer household is sufficiently wealthy and/or has sufficient access to credit, it can dissociate each period's consumption flow from the corresponding period's realized income flow. In a "bad" period it can dissave or borrow while in a "good" period it can replenish its wealth or repay its debt. An extension of the logic is that if farmers have differential access to credit, they should show different risk taking behavior even when they have identical risk preferences (Just and Zilberman 1983, Eswaran and Kotwal 1990).

I.B.3. The Off-farm Labor Market and its Connection with Crop Choice

A village off-farm labor market is not an uncommon feature in developing country agriculture. The cultivator households buy and sell their surplus labor in excess of their on-farm family labor supply in this market. As it is documented in the ICRISAT study of the semi-arid areas of India, this market often has a two-tier structure. On one tier there are the daily "casual" laborers, while on another tier there are the "permanent" laborers who are hired in advance for multiple periods of time at a fixed wage rate. In the semi-arid areas of India, the bulk of off-farm labor income is earned in the form of "casual" labor, especially in the daily off-farm wage labor market. This daily wage labor market is "impersonal" in nature

(Walker and Ryan 1990, pp.110), unlike other markets where labor is often tied with credit or tenancy arrangements. Employers are indifferent about caste and other considerations, and employees also have freedom to choose among different employers. Contracts are typically negotiated for a short period of time, usually a single day or two, and payment is made each day for an agreed upon number of hours. Another form of off-farm casual labor employment is the contract submarket, where laborers are organized by an intermediary and compensated on a piece-rate basis for a specified job for government or non-government agencies. One comparison between the daily casual off-farm labor market and the contract submarket is that daily earnings often are higher in the latter, but the contract submarket also is characterized by longer hours and/or more strenuous work (Section IV.D).

One possible testable hypothesis is that crop choice decisions are connected to off-farm labor earnings. If the weather shocks turn out to be positive, the farmers of the village will have a higher output in the harvest season, which implies that the demand for on-farm work will also be higher. Since the farmers will need to hire the excess demand of on-farm work in their farms over and above their own family labor supply, this translates into a higher demand for off-farm labor in the village. This way a positive weather shock is associated with a higher wage and lower unemployment rate in the village off-farm labor market. On the other hand, a negative weather shock is associated with a lower wage and higher unemployment rate. Wage and unemployment rates in the off-farm labor market in the harvest period are unknown to the farmer at the start of the agricultural season. The question that follows is *how do the farmers react to this employment uncertainty in the labor market while choosing crops to plant?* So far no study has investigated the relationship between crop choice decisions of the cultivator households and their expectations about conditions in the off-farm labor market at a later stage. One can argue that farmers would rather plant less risky crops in the face of a higher employment uncertainty in the off-farm labor market. This can be considered as a form of a conservative *ex ante* risk-management strategy given their unfavorable expectations of off-farm labor income. Conversely farmers would rather plant more risky crops if they expect a lower level of unemployment in the off-farm labor market since they can more readily fall back upon the available insurance in the form of income earnings from that market should their crop earnings suffer from negative income shocks. Another point to note is that households with more wealth or access to credit are in a better position to cushion themselves from the worst impacts of subsequent labor market shocks; thus the impact on their crop choice decisions from expectations of labor market shocks could turn out to be small compared to the case of households with less wealth or less access to credit.

The topic can be further explained with the help of the following diagram (Figure 1). Three possible chains of impacts can be traced towards the crop choice decision of a cultivator household in a season of a given year. These are (1) the *ex post* impact of the previous year's income through savings or dissavings, (2) the *ex ante* impact of uncertainty regarding the current season's labor income earnings, and (3) the *ex ante* impact of uncertainty regarding the next season's income earnings. This study concentrates on the second possible impact.

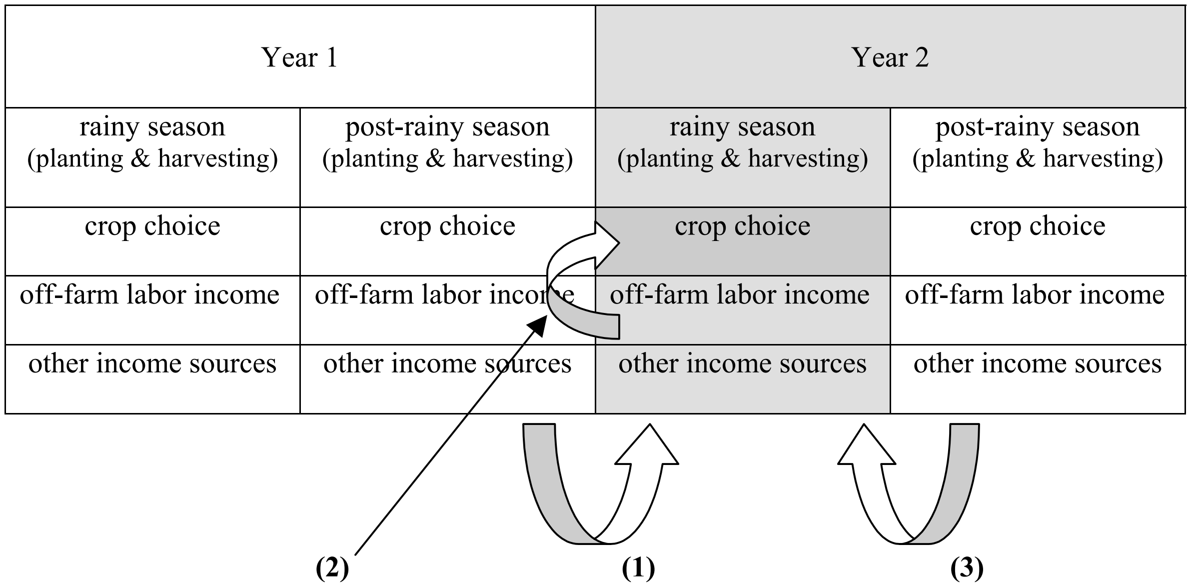

Figure 1. Diagram of the Impacts on Crop Choice Decisions.

I.C. Research Objectives

The research objectives of this study are as follows.

(1) To investigate the impacts of uncertainty over the off-farm labor market on cultivator households' *ex ante* crop choice decisions.

(2) To investigate the impacts of structural aspects of the off-farm labor market on cultivator households' *ex ante* crop choice decisions.

(3) To investigate the mechanisms through which weather factors create uncertainties in both on-farm crop production and the off-farm labor market and to understand the interconnections between the two.

CHAPTER II

OVERVIEW OF RELATED LITERATURE

The literature on this topic covers different branches of empirical development microeconomics and agricultural economics, primarily in a developing country context. The current chapter presents a brief overview.

II.A. Risk in Agricultural Economics

Roe and Graham-Tomasi (1986), Chavas and Holt (1990, 1996), Coyle (1999) and Larson and Plessman (mimeo 2002) are some of the papers that discuss yield and/or price risk.

On the issue of weather risk and its impact, Rosenzweig and Binswanger (1993) utilize data from the ICRISAT survey in India to examine how the composition of productive and non-productive asset holdings varies across farmers with different levels of total wealth and facing different degrees of weather risk. Their paper supports the hypothesis that the composition of asset portfolios is significantly influenced by farmers' aversion to risk, household wealth and degree of rainfall variability. They find that farmers in riskier environments select portfolios of assets that are less sensitive to rainfall variation and thus less profitable. My study develops a similar theme.

In my study it is maintained that the developing country farmers are *risk averse*. The empirical support for this assumption comes from Binswanger (1980) and Binswanger and Sillers (1983). Binswanger (1980) follows methods of experimental psychology and designs a series of games to measure risk preferences among a sample of villagers in the semi-arid areas of India. His experimental measures indicate that, "*at high payoff levels, nearly all individuals are moderately risk-averse with little variation according to personal characteristics*" (pp. 395). Binswanger and Sillers (1983) discuss evidence from surveys on farmers in different developing countries and conclude that they "*are almost universally risk averse and that risk aversion may not vary greatly between different cultural or agroclimatic environments, nor be very sensitive to variations in wealth*" (pp. 18).

II.B. Decision Making in Agriculture

The model in this study treats agricultural production as a process of sequential decision making. This approach is pursued in a number of papers, e.g., Antle (1983b), Antle and Hatchett (1986), Innes (1993), Fafchamps (1993), Saha (1994) and Weninger and Zhao (mimeo 2002). Earlier papers typically employed single-equation estimates of econometric production function models. Antle (1983b) mentions that this single-equation approach is based on a strong assumption that production inputs are chosen as part of a one-period decision problem. He argues that these models fall short of reality in the sense that, particularly in agriculture, both short run and long run production decisions are based on multi-period, dynamic optimization problems wherein inputs are chosen and applied at different times. The paper proposes that the farmers' optimal input choices be regarded as optimal controls in a stochastic control problem.

Innes (1993) develops a two-season subsistence farming model framework in his paper, which is further extended by Saha (1994). In these papers farmers have two decision points in a given year, each decision point preceding one of two seasons-- namely the planting season and the harvesting season. Innes (1993) develops a model that assumes that there is only one cropping period (with two seasons as above) per year, and that a single crop is grown, sold, purchased and consumed from own production by farmers. Farmers' consumption of the produced crop, "other goods" and leisure takes place at both planting and harvest seasons. Production inputs (including the farmers' own labor) are chosen at the time of planting, while the sales and storage decisions of the produced crop are made at the time of harvest. Farmers' consumption of maize during the planting season comes out of storage from the prior harvest and purchases from the government marketing authority. As an improvement over the static analysis this two-season choice structure permits a characterization of how one season's prices affect another season's optimal choices. Saha (1994) finds that by taking into account the seasonal dimensions of household decisions one reaches analytical results that suggest households' optimal consumption, production and labor supply choices are not *separable* under risk-averse preferences-- results that are markedly different from those models prevalent in the mainstream of agricultural household literature.

Benjamin (1992) tests for *separation* of household consumption (labor supply) and production (labor demand) decisions. He argues that, controlling for wage in a complete and competitive market, supply side variables should not influence labor demand and vice versa. An imperfect labor market and other violations of the *separation* assumption imply that demographic variables affect farm labor allocation. This *non-separation* can cause market imperfections like hiring-in or off-farm employment constraints, or differing efficiencies of family and hired labor. The null hypothesis of the paper is that farm employment is determined according to the neoclassical labor demand model and that deviations from the usual first order conditions are correlated with household composition. The hypothesis is tested with rice farmers' data from Java, Indonesia. Most of the econometric results point to the validity of the *separation hypothesis*. Another result is that where *separation* is less certain, auxiliary evidence suggests that farmers might be constrained on the demand side, which is a point to note for my study.

One paper that discusses the issue of farmers' adjustment to risk in a *safety-first framework* is Shahabuddin, Mestelman and Feeny (1986). In a *safety-first framework*, decision makers are concerned with maximizing their chances of survival. Choices made by farmers do not depend on differences in their attitude towards risk, but on the differences in their subsistence needs, resource endowments and perceptions of the riskiness among competing activities. As a concrete example, if the "disaster" income level of the farm family exceeds its expected income from farming operations, then in an attempt to minimize the probability of disaster, it may tend to "gamble" in its choice of crop portfolio. The farm family may take risk in order to maximize its chances of survival by devoting greater resources to riskier but more profitable (higher expected profit) crops. On the other hand if its subsistence requirements are lower than its expected income from farming, then it can afford to choose a less risky crop portfolio with lower expected returns. This does not necessarily imply that the second family is psychologically more risk-averse than the first one. The study uses information from a field survey conducted in Bangladesh. While the evidence provides support for the *safety-first hypothesis* in the sample regions, the difference between the share of land going to riskier crops when disaster income is greater than expected income and the share when disaster income is less than expected income is not found to be statistically significant by different from zero. While my study concentrates on more familiar risk aversion aspects of household behavior instead of a *safety-first framework*, this remains an interesting proposition regarding the household decision making process.

Kurosaki (1998) provides a comprehensive examination of household behavior under uncertainty in the Pakistan agricultural context. Unlike previous papers this one uses a model that incorporates incomplete insurance markets and considerations for household food consumption. His estimation results show that when both income and consumption prices are stochastic, household's production choices are affected by their willingness to bear risk as well as by their ordinal consumption preferences for individual goods. The central theme of this paper is the mixed farming strategies and farmers' use of livestock and other secondary sources of living as sources of *back-up support*.

II.C. The Off-farm Labor Market

Rose (1993) is a study of the *ex ante* effect of the riskiness of the distribution of rainfall as well as the *ex post* effects after realization of weather shocks on the labor supply decisions of cultivator households. This study discusses the interconnections between risk and labor markets with data from the ICRISAT survey in India. One conclusion of the study is that farmer households facing greater dispersion in rainfall allocate less labor towards risky own-farm production and more to the less risky alternative activity-- the off-farm labor market. Because farmers' labor allocation switches more towards the off-farm labor market at the expense of own farm production in the face of greater dispersion of risk, both profits and total incomes suffer, on average. Another finding is that labor markets work as a *back-up support* for the sake of household income stability. In periods of bad weather and low rainfall households partially compensate for shortfalls in production income through work in the labor market. Non-agricultural employment opportunities reduce the riskiness of market labor, making it a more attractive activity for risk-averse households. The accessibility of a factory or small-scale industry draws labor from own-farm production. This line of argument placing the off-farm labor market as a *back-up support* for household income stability is followed in my own research.

Kanwar (1999) reaches a different conclusion regarding the viability of use of employment in the off-farm labor market as a *back-up support* by the cultivator households. He deals with the issue of the impact of revenue risk on the hiring-out behavior of owner-cultivators, while taking into account labor market risk due to the fact that hiring out is not certain. His is one of the few papers that mention employment risk in the off-farm labor market. He uses a farm household model to deal with the issue and bases empirical tests on the ICRISAT data set from India. The central question addressed is whether a decrease in revenue uncertainty (in crop income) will leave unchanged, increase or decrease off-farm labor supply. The paper finds that since production risks are carried forward into the local labor market, households might not be able to use the labor market as a hedge against production risk.

Kochar (1999) on the other hand focuses on the responsiveness of the market hours of work of Indian farm households to idiosyncratic or household-specific shocks to crop income. The paper argues that the households need not go for costly mechanisms such as asset transactions to mitigate crop income shocks if they can successfully resort to the off-farm labor market for that purpose, provided labor markets are flexible enough to accommodate a reallocation of labor from family farm to the wage labor market. The paper finds that household males increase their market hours of work in response to unanticipated variations in crop profits, which by itself does not reflect the desire of households to smooth consumption. With well-functioning labor markets, farm-specific shocks would result in a shift from own farm production to the labor market even if households had access to insurance markets. But conditional on hours of work, crop income shocks have a negative effect on consumption, confirming that the ability to protect consumption from crop income shocks depends, in most parts, on adjustments in hours of work.

Maitra (2001) tests for consumption and leisure insurance against unanticipated income shocks for the cultivator households, using data from the ICRISAT survey in semi-arid areas of India. While the earlier literature primarily focuses on the role of credit and state contingent transfers in smoothing consumption, this paper finds that credit markets are favorably biased towards medium and large farmers while small farmers have to depend on off-farm labor work to smooth their household consumption. Small farmers vary their market participation, substituting own farm work with labor market participation to smooth income and therefore consumption. Consumption smoothing for the small farmers is obtained not at the cost of volatile leisure but by making compensating changes in participation in the off-farm labor market.

Lamb (2003a) develops a two-period model in which a risk-averse farmer household uses off-farm labor supply to mitigate the effects of production shocks *ex post*, which leads to more efficient *ex ante* production choices in the presence of production risk, i.e., greater use of chemical fertilizer. Controlling for exogenous weather risk, this paper positively relates fertilizer use with the depth of the off-farm labor market. Farmers tend to use more fertilizer the lower the unemployment rate in the off-farm labor market and the higher the share of nonagricultural work in total off-farm labor work in that market. This paper suggests that off-farm labor markets and on-farm production may have a complementary relationship in risky production environments. This idea is further investigated in my research.

II.D. Crop Choice

It is commonly observed in developing country agriculture that large farmers tend to devote a larger share of their land to cash crops than do small farmers. Different explanations have been put forward to explain this observation, such as the presence of credit constraints, lumpy investments, technological differences giving advantage to large-scale or small-scale farming, and differentials in relative factor costs across farms (Feder 1980, Feder, Just and Zilberman 1985, Eswaran and Kotwal 1986), and farmers' ability to sustain risk (Binwanger 1980, Shahabuddin, Mestelman and Feeny 1986). In contrast, Fafchamps (1992) argues that crop choice decisions arise because of transactions cost. Food crops are mostly consumed by producers while cash crops are not meant for household food consumption. In the absence of integrated food markets, Third World farmers allocate land to cash crops provided that their food security is insured. Fafchamps argues that even when food markets do exist in Third World countries, food security is best assured by food self-sufficiency. Hence, only wealthier farmers with their wealth as a back-up support in case of adverse contingencies are able and willing to grow cash crops. Since basic staples constitute a large share of total consumption and have low income elasticities, farmers need to protect themselves against food price risk, arising from thinness in rural food markets. Wealthier farmers spend proportionally less on food. They therefore allocate proportionally less of their land to food crops. As agricultural productivity increases and transport costs fall, rural food markets become more integrated and less affected by local production shocks. One would expect food self-sufficiency concerns to diminish and standard portfolio diversification to take over. Simulation results in this paper indicate that food market integration reduces the need for food self-sufficiency. While Fafchamps emphasizes the cash crop-food crop debate in explaining crop choice behavior, my research proceeds in a different direction where off-farm labor market employment uncertainty plays a role in the crop choice decisions.

Goetz (1993) discusses the cash crop-food crop debate in the context of land-abundant African agriculture. Interlinked market arrangements combine the markets for labor, land, credit and insurance within a single contract or transaction. On the surface, these transactions appear to be absent in sub-Saharan Africa, but this paper illustrates the ways such institutions do arise in the African context under certain preconditions. It is argued that the lack of a land market along with some other conditions leads to the failure of labor and private sector credit markets. In response indigenous institutions have evolved to cope with the market failures. Goetz shows that the interrelated failure of specific agricultural markets (land, credit, wage labor) gives rise to indigenous institutions, such as horizontally extended families, to cope with that failure. Cash cropping opportunities allow further indigenous response in the form of non-family labor utilization and the strengthening of vertically extended relationships. This in turn facilitates intrahousehold specialization in cash and food crop production, with exchange taking place within households rather than in less conventional market places. In this way, interlinkages are created between the market for cash crop inputs and outputs as well as seasonal labor and the level of food crop production. Because of these linkages, Goetz argues that the cash crop versus food crop issue poses less of a dilemma than was previously believed, at least in the land-abundant sub-Saharan African context.

Omamo (1998) reinvestigates the cash crop-food crop debate in the context of transport cost and sheds new light onto it. In Siaya district, Kenya, smallholders are known to regularly allocate larger shares of resources to low-yielding food crops than they do to cash crops that have higher market returns. The paper incorporates costly exchange into an agricultural household model, and shows that these seemingly inefficient cropping choices of smallholders in Kenya can be explained as rational food import substitution given high transport costs in the product markets. The writer suggests a different definition of a *cash crop*: one whose marketing cost is low relative to its market price and whose share in household expenditure is small. According to this definition, some of the foods produced in the study region--beans, green grams, groundnuts and sesame--can be considered cash crops. One particular implication of the paper is that relatively more land is devoted to cash crops and less to food crops the closer are the households to market centers in the Siaya district, Kenya.

Lamb (mimeo 2002) is one paper that verifies the role that risk plays in crop choice decisions and studies how wealth affects crop choices. As long as production risk is uninsured and households are risk averse, households will tend to choose less risky crop mixes in order to mitigate impacts of weather uncertainty *ex ante*. Therefore average farm profits will be smaller, and consumption and welfare accordingly will be lower than would be the case with profit-maximization crop mixes chosen by the risk-neutral decision makers. The paper finds that farmers' choices of crop mix are affected by weather risk in the two ICRISAT villages investigated here. The impact is stronger, the poorer the household; since poorer households are less able to smooth consumption *ex post*, their *ex ante* choices are further from the expected profit maximizing crop mix. Empirical results in this paper support the argument that risk aversion plays a role in crop choice and that poorer households allocate land to a mix of crops with lower risk (and lower average profits) with some with higher risk (and higher average profits). While this paper concentrates on the impact of wealth on crop choice decisions, my study deals with a possible impact from another source: uncertainty in the off-farm labor market.

II.E. Crop Choice and the Off-farm Labor Market

An investigation of farmers' crop choice behavior from the perspective of off-farm employment uncertainty is yet unexplored in the literature. Because crop income and off-farm labor market income are two main components of household incomes for a large population of farmers in developing countries, and because a number of the aforementioned studies argue that the cultivator households use income from participation in the off-farm labor markets as a form of insurance against shocks in crop income, a more focused study on the interconnections between the two is worthy of consideration. Research on this issue may lead us to important policy recommendations, which might turn out to be helpful in improving the standard of living of developing country farmers.

CHAPTER III

THE MODELS

In this chapter, a basic two-period model and its extension describing the cultivator households' crop choice decisions under uncertainty of yields in production and in the labor market environment is presented. The basic model describes the issue within a two period model framework where decisions taken at one period affect optimal choices in the other period. In the extension, the cultivator households are allowed to have instruments at their disposal to mitigate the impacts of adverse weather shocks.

III.A. The Two Period Model

III.A.1. Introduction

The household is assumed to be an expected utility maximizer in this model. It maximizes expected utility of income EU(I) where I is income. The utility function of the household is strictly concave and has the properties $U'(I)>0$ and $U''(I)<0$; the household is risk averse. It is also assumed that savings is absent and current consumption is equivalent to current income. Thus the household can alternatively be shown as maximizing expected utility of consumption EU(C), with its utility function having the properties $U'(C)>0$ and $U''(C)<0$.

There is a single agricultural crop season in the year and there are two decision points in that season, t_1 and t_2, each one preceding one period, period 1 (planting) and period 2 (harvesting) respectively. The household has two sources of income-- on-farm income from crop production and off-farm labor income from the village daily casual wage labor market. I restrict my attention to these two sources of income for the cultivator households but in reality the household may have access to other sources of income and earnings as well, such as remittances or transfers. This model also does not allow for credit or borrowing. This is restrictive not to take into account any of these *ex post* risk coping strategies since in reality the household may have some access to credit or borrowing, but this allows me to focus exclusively on the mechanisms of the *ex ante* risk-management strategy in the form of crop choices vis-à-vis uncertainties regarding the off-farm labor income. The household has a fixed amount of cultivable land (set to unity) at its disposal and has to distribute this land between two crops, 1 and 2. Of these two crops, crop 1 is characterized by low mean and low variance of returns whereas crop 2 is characterized by high mean and high variance of returns. Another point to note is that crop 1 is characterized by less susceptibility to realizations of rainfall shocks compared to crop 2. Thus the household has a portfolio selection problem. The household takes into account its expectations regarding rainfall shocks, crop prices and wage rates and unemployment rates in the village off-farm labor market while deciding on allocation of land to different crops. This allocation of land provides the household with an opportunity to partly influence the returns from its income generating activities, since a large allocation of land to crops with high means and high variances heightens the exposure of the household to realizations of rainfall uncertainty whereas a low allocation of land to those crops reduces household exposures to these shocks.

At time t_1, the start of the planting period, the household decides on the allocation of the unit amount of cultivable land between crops 1 and 2. In between two decision points, t_1 and t_2, the rainfall uncertainty γ is resolved, which is measured as the difference between actual rainfall and expected rainfall. Realizations of rainfall shocks affect household income through different ways as outlined in Figure 2.

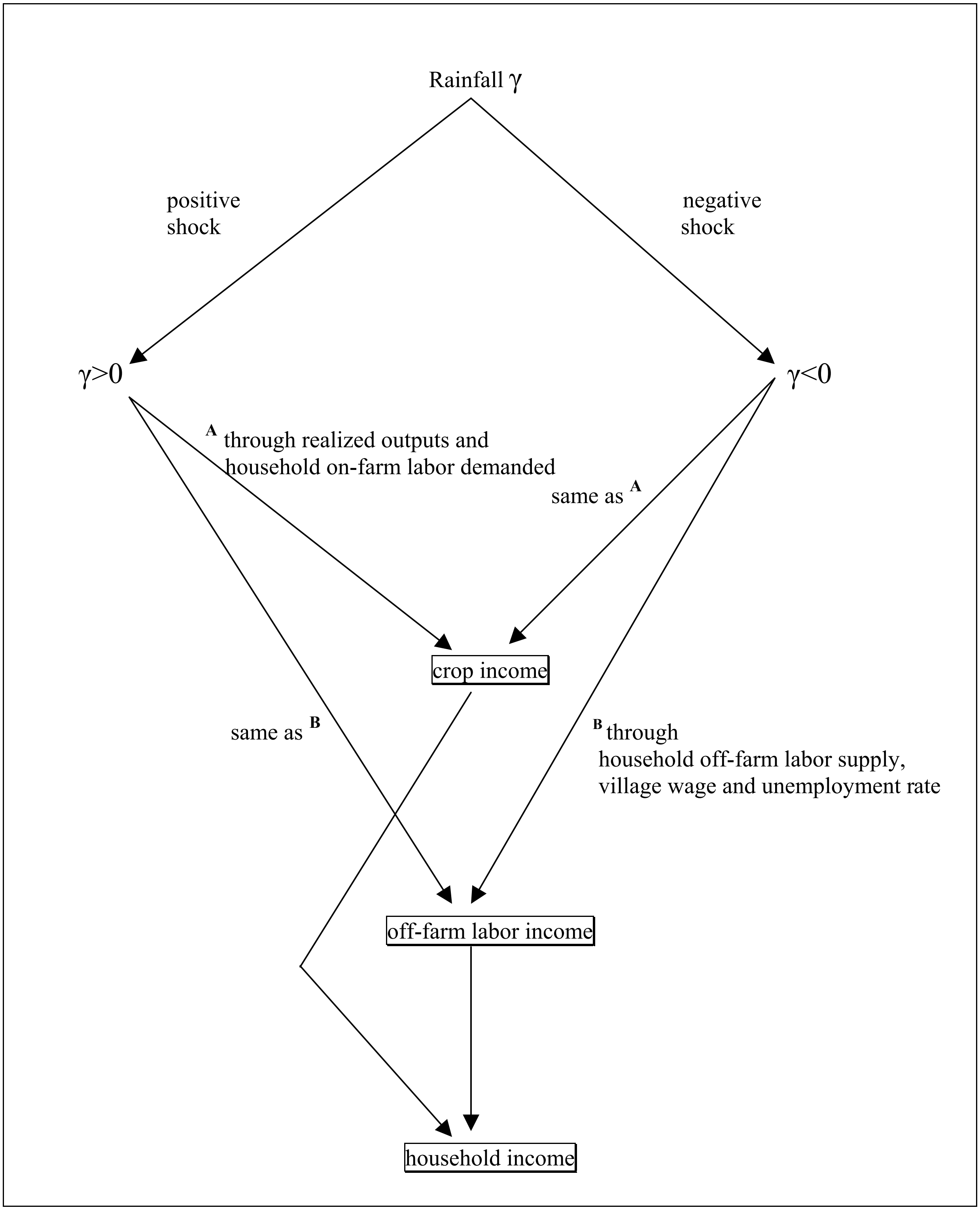

Figure 2. The impacts of the rainfall shocks on household income.

As Figure-III.1 illustrates, not only crop outputs are affected by negative or positive realizations of rainfall shocks, but they also affect on-farm labor demanded for the crops at the harvest period because a "good" harvest requires more on-farm labor than a "bad" harvest. Particular realizations of rainfall shocks affect wage and unemployment rates in the village labor market as well. At time t_1 the household does not know what the value of γ will turn out to be for the ensuing monsoon, but it knows its distribution. I assume γ is an independent and identically distributed random variable with mean zero and variance unity.

At time t_2, the start of the harvest period, the household decides on an allocation of harvest period family labor to crops 1 and 2.

The household has a labor allocation decision in period 1 as well, but introducing the period 1 labor allocation problem would complicate the model to a large extent because this would increase the total number of choices from three to five. To the extent that on-farm family labor demanded for crops 1 and 2 in the first period are proportional to on-farm family labor demanded for the same crops in the second period, omitting labor allocation problems from the first period would not bias the results. This model also assumes that all consumption takes place in period 2.

In Figure 3 L_1 and L_2 are period 2 on-farm family labor demanded for crops 1 and 2. The household crop choice decision is specified as a land allocation decision between crops denoted by k ($0 \leq k \leq 1$), defined as the proportion of a unit of cultivable land allocated to the low-mean and low-variance crop 1 (the rest, $1-k$, is allocated to crop 2).

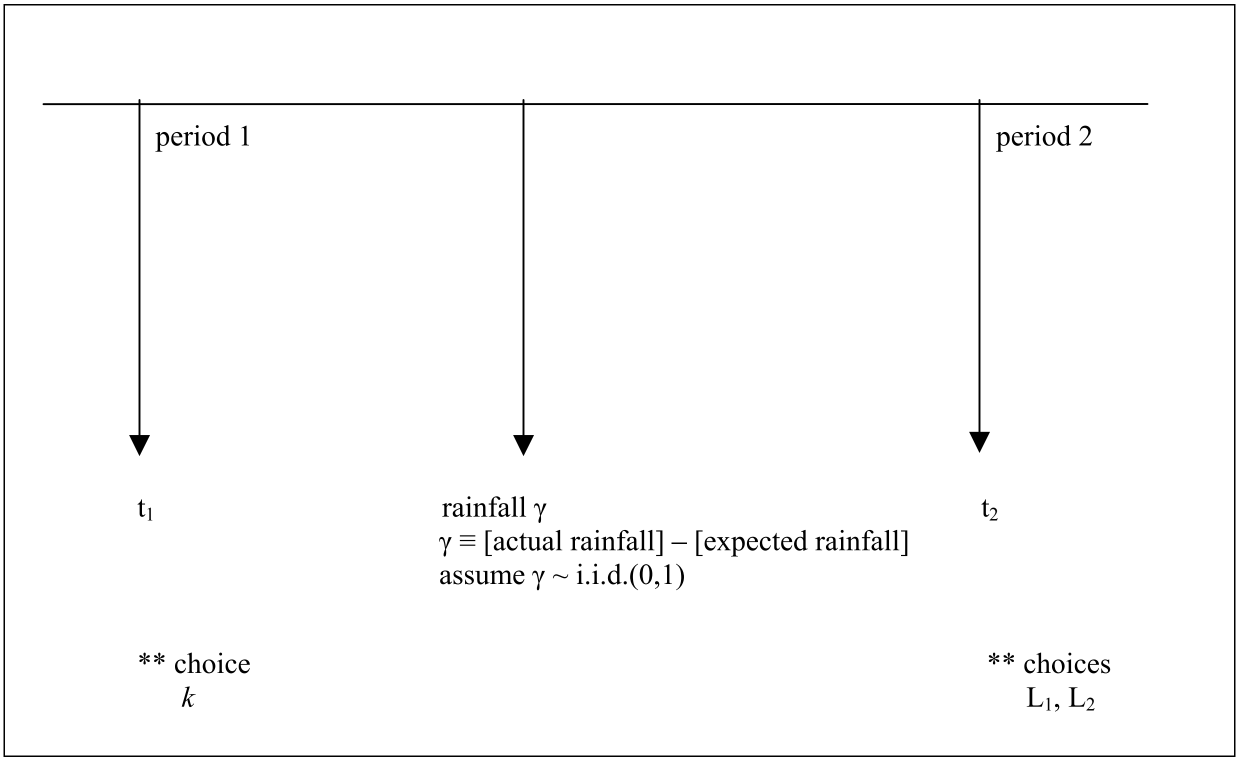

Figure 3. The Structure of the Two Period Model.

III.A.2. Specifications

The first specification I consider is of the random crop output terms. I need to specify these terms in such a manner that they sufficiently account for different means and variances of crop yields as well as their different levels of susceptibility to realizations of rainfall shocks. In a related context, Just and Pope (1978) discuss appropriate production function formulations under risk, and find that commonly used formulations are restrictive and may lead to biased results. They argue that *"…a useful production function should possess sufficient flexibility so that the effects of inputs on the deterministic component of production is different than on the stochastic component*" (Just and Pope 1978, pp.67). They propose introducing some function of the inputs which perturbs the effects of the disturbance in such a way that the relationships between inputs and risk are not determined solely by the relationships between inputs and expected output (Just and Pope 1978, pp.73). They observe that this specification satisfies a set of postulates that seems to be *a priori* desirable which other more conventional specifications fail to satisfy, and provide estimating procedures that are consistent and asymptotically efficient. In this model I follow Just and Pope (1978) in specifying the production function terms for the random crop outputs.

Crop production functions are specified as:

Crop 1: $Q_1 = f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\gamma$

Crop 2: $Q_2 = f^{(2)}(1 - k, L_2) + h^{(2)}(1 - k, L_2)\gamma$

$E(\gamma) = 0$; $Var(\gamma) = 1$

$h^{(1)}(k, L_1)$, $h^{(2)}(1 - k, L_2) > 0$.

Here, Q_1 is the output of crop 1, which consists of the deterministic component, $f^{(1)}(k, L_1)$, which relates inputs to mean output of the crop and a stochastic component, $h^{(1)}(k, L_1)\gamma$, which relates inputs to the variance of output of that crop. Q_2 is the corresponding expression for crop 2. The inputs are the share of cultivable land and harvest period labor allocated to the crop in question; these inputs are assumed gross complements in production. The randomness in crop outputs is contributed by the rainfall shock γ with mean zero and variance unity. This shock affects the two crops differently, captured by the term $h^{(1)}(k, L_1)$ in the case of crop 1 and $h^{(2)}(1 - k, L_2)$ in the case of crop 2.

One point that needs to be noted is that the specification followed here is a simple restatement of a standard multiplicative random effects specification of random crop outputs common in literature. This can be shown by the following exercise. A conventional multiplicative random effect that enters into a random production function can take the following form: $Q=\theta f(x)$ where Q is a random crop output and x is input while θ is a random term with mean $\bar{\theta}$. Defining $\gamma \equiv \theta - \bar{\theta}$, $h(x) \equiv f(x)$ and $y(x) \equiv \bar{\theta} f(x)$ one can obtain $Q = y(x) + \gamma h(x)$. This is the Just and Pope (1978) specification (Feder 1980, pp. 266).

The cultivator household knows the means and variances of the crops and their relative magnitudes.

$E(Q_1) = f^{(1)}(k, L_1)$

$E(Q_2) = f^{(2)}(1 - k, L_2)$

$Var(Q_1) = [h^{(1)}(k, L_1)]^2$

$Var(Q_2) = [h^{(2)}(1 - k, L_2)]^2$

$E[Q_1(\bar{k}, \overline{L_1})] < E[Q_2(\bar{k}, \overline{L_1})]$ (Assumption)

$Var\ Q_1(\bar{k}, \overline{L_1}) < Var\ Q_2(\bar{k}, \overline{L_1})$ (Assumption).

The deterministic components of the production functions, $f^{(1)}$ and $f^{(2)}$, follow properties of a strictly concave production function. In the case of $f^{(1)}$,

$\partial f^{(1)}/\partial L_1 > 0$, $\partial f^{(1)}/\partial k > 0$

$\partial^2 f^{(1)}/\partial L_1^2 < 0$, $\partial^2 f^{(1)}/\partial k^2 < 0$

$\partial[\partial f^{(1)}/\partial L_1]/\partial k = \partial[\partial f^{(1)}/\partial k]/\partial L_1 > 0$ (in a gross complementary sense)

$[\partial^2 f^{(1)}/\partial L_1^2][\partial^2 f^{(1)}/\partial k^2] - [\partial^2 f^{(1)}/\partial k \partial L_1]^2 > 0.$

In the case of $f^{(2)}$,

$\partial f^{(2)}/\partial L_2 > 0$, $\partial f^{(2)}/\partial(1 - k) > 0$

$\partial^2 f^{(2)}/\partial L_2^2 < 0$, $\partial^2 f^{(2)}/\partial(1 - k)^2 < 0$

$\partial[\partial f^{(2)}/\partial L_2]/\partial(1 - k) = \partial[\partial f^{(2)}/\partial(1 - k)]/\partial L_2 > 0$ (in a gross complementary sense)

$[\partial^2 f^{(2)}/\partial L_2^2][\partial^2 f^{(2)}/\partial(1 - k)^2] - [\partial^2 f^{(2)}/\partial(1 - k)\partial L_2]^2 > 0.$

The abovementioned properties of the deterministic components follow a conventional specification for a production function. For example, the term $\partial f^{(1)}/\partial L_1$ can be interpreted as the change in the mean output of crop 1 for a unit change in the variable input L_1. The signs of these marginal product terms should be positive for all inputs and the signs of the second partial derivatives of outputs with respect to inputs should be negative following strict concavity of the production function.

The properties of the stochastic components on the other hand depend on the nature of the specific input in consideration and with respect to the particular crop in question (Just and Pope 1978, pp.74-75; Pope and Kramer 1979, pp.491). The marginal production risk from an additional unit of input L_1 for crop Q_1, defined as

$\partial Var(Q_1)/\partial L_1=2[h^{(1)}(k,L_1)]\ [\partial h^{(1)}(k,L_1)/\partial L_1]$,can be positive, negative or zero depending on the sign of the term $[\partial h^{(1)}(k,L_1)/\partial L_1]$. One can consider the term $[\partial h^{(1)}(k,L_1)/\partial L_1]$ as contribution to the riskiness of producing crop 1 from employing an additional unit of on-farm labor L_1. The input L_1 is risk increasing (risk decreasing) if $[\partial h^{(1)}(k,L_1)/\partial L_1]$ is positive (negative); it is neither risk increasing nor risk decreasing if $[\partial h^{(1)}(k,L_1)/\partial L_1]$ is zero. Similarly input L_2 is risk increasing (risk decreasing) if $[\partial h^{(2)}(k,L_2)/\partial L_2]$ is positive (negative), and it is neither risk increasing nor risk decreasing if $[\partial h^{(2)}(k,L_2)/\partial L_2]$ is zero. Here I assume that both on-farm labor and the share of cultivable land allocated to the crop are risk-increasing inputs. The land input is risk increasing because raising the share of cultivable land allocated to a particular crop increases the scale of production of that crop, thereby raising variability of output from that crop. The case of labor as a risk increasing or risk decreasing input, on the other hand, is not straightforward. It is possible to argue that labor is risk decreasing in the sense that a more intensive use of harvest period on-farm labor can help reduce the damage done to crop yield as a result of a negative rainfall shock. But, in the context of this particular model, harvest period on-farm labor is tied to the share of land allocation in a complementary way, i.e., a higher share of land allocation for a crop would lead to a higher amount of harvest period on-farm labor needed for that crop. Since land allocation is a risk-increasing input, labor is also considered risk increasing.

Following properties of the deterministic portions of the production functions I specify properties of the stochastic portions as (here the stochastic portion is also assumed strictly concave), in the case of $h^{(1)}$,

$\partial h^{(1)}/\partial L_1 > 0$, $\partial h^{(1)}/\partial k > 0$

$\partial^2 h^{(1)}/\partial L_1^2 < 0$, $\partial^2 h^{(1)}/\partial k^2 < 0$

$\partial[\partial h^{(1)}/\partial L_1]/\partial k = \partial[\partial h^{(1)}/\partial k]/\partial L_1 > 0$.

In the case of $h^{(2)}$,

$\partial h^{(2)}/\partial L_2 > 0$, $\partial h^{(2)}/\partial(1-k) > 0$

$\partial^2 h^{(2)}/\partial L_2^2 < 0$, $\partial^2 h^{(2)}/\partial(1-k)^2 < 0$

$\partial[\partial h^{(2)}/\partial L_2]/\partial(1-k) = \partial[\partial h^{(2)}/\partial(1-k)]/\partial L_2 > 0$.

The period 2 price terms are specified as:

price of crop 1: p_1

price of crop 2: p_2.

Here, p_1 is the expected period 2 price of crop 1 and p_2 is the expected period 2 price of crop 2. Output prices in this model are exogenous, implying zero impact of local weather variations on output prices, assuming that output markets are integrated. I assume that period 2 crop prices are "correctly" forecast at the start of period 1, thereby subsuming the discussion of the formation of price expectations and possible forecasting error on behalf of the cultivator households. This is done in order to keep the model analytically simple.

The third consideration is the wage rate in the village off-farm labor market. Wage rates are affected by shocks in rainfall. A positive rainfall shock raises on-farm labor demanded for crops planted. To the extent that on-farm family labor does not expand so much as to match the higher amount of on-farm labor demanded for the crops planted, the households have to depend on hired-in labor to match the deficit in on-farm labor demanded in their plots. Since rainfall shocks are shared experiences in the village across households, a positive rainfall shock will cause higher demand for hired-in labor by the cultivator households in the village. To the extent that changes in the supply of labor in the village off-farm labor market lags behind increases in the demand for labor in that market and to the extent this market is not fully integrated with a broader regional labor market, wage rates for labor in that market will increase.

There could be particular *institutional factors* involved which might prevent the wage rate from reaching exactly a market-clearing level-- in other words once unemployment exists at the initial wage rate this may still persist at the new wage rate in the market after the shock. Since the wage rate at the labor market may move from one disequilibrium level to another, it is difficult to understand the impact of rainfall shocks on the unemployment rate. One possible outcome is that the unemployment rate decreases as a result of positive rainfall shocks-- this can be caused by a sharp increase in labor demand unmatched by increases in labor supply in the market. One can consider the situation where wage rates in the off-farm labor market are not at the market-clearing rates and unemployment persists in the market at the going wage rates. This is the case for the off-farm labor markets in the semi-arid tropics region of India (Chapter IV), where unemployment rates have been found to be positive in each of the survey years and at each of the villages. The unemployment rates are affected by seasonal variations, local crop-labor use as well as gender-based segmentation in that market (Walker and Ryan 1990, pp. 122-124). Based on this empirical evidence, one can assume unemployment in the off-farm labor market as a *fact of life* in the context of this model.

A negative rainfall shock, in contrast, causes wage rates in the village off-farm labor market to fall, to the extent increases or decreases in the market supply of labor lag behind decreases in the market demand for the same. It is therefore possible to specify harvest period labor market wage rates as functions of realizations of rainfall shock, such as this linear function,

$$W_K = \overline{w_k} + (1 - d_k)\gamma \quad (0 \le d_k \le 1).$$

Here W_K is the realized period 2 wage rate while $\overline{w_k}$ is the expected wage rate and $(1 - d_k)$ is a measure of the impact of the rainfall shock on the realized wage rate. Here d_k is the *depth* of the village off-farm labor market that counteracts against the impact of shocks in rainfall (Lamb 2003a, pp. 363).

The mean value of the realized period 2 wage rate is $\overline{w_k}$ and variance is $(1 - d_k)^2$.

The fourth consideration is of the distribution of household family labor among competing demands for it. The household has a given total labor time, T, in period 2 that it allocates among three alternative uses: on-farm family labor applied to crop 1 (L_1), on-farm family labor applied to crop 2 (L_2) and the residual time to daily wage labor in the off-farm labor market (Figure 4).

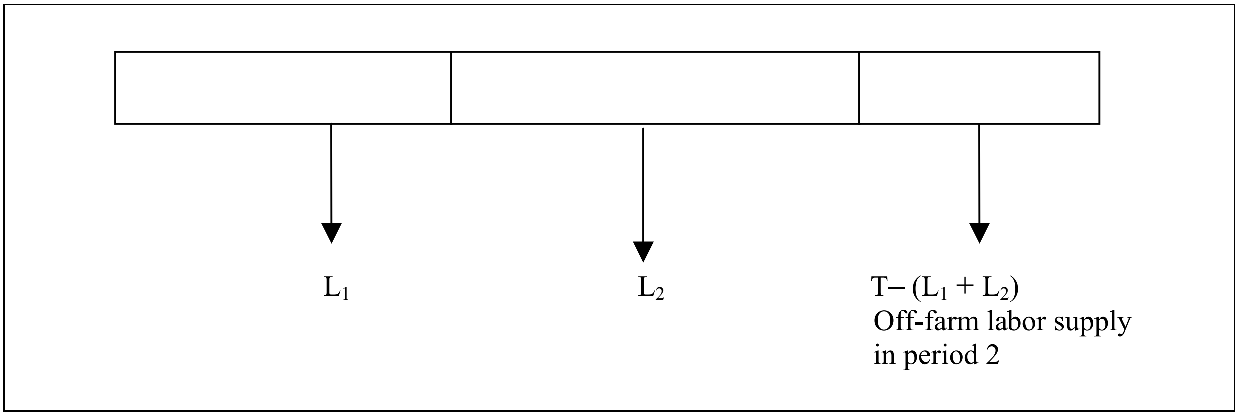

Figure 4. Household labor allocation of a given total household labor time T

Here are some assumptions that are maintained throughout the model regarding household labor allocation and other related decisions,

(i) Households consider on- and off-farm labor as perfect substitutes.

(ii) Households do not hire-in labor. In other words, in each period, there is an *interior solution* to the household labor allocation problem such that on-farm family labor allocated to the crops sums up to less than the total given household labor time. This implies that the off-farm labor supply by the household in period 2 ($T - L_1 - L_2$) is nonnegative.

(iii) Bullock labor used (family-owned or hired-in) to crops 1 and 2 in period 1 is proportional to family on-farm labor applied to crops.

(iv) The amount of fertilizer and insecticide applied to the crops is proportional to family on-farm labor applied to the crops in period 1.

(v) Leisure in period 2 is a fixed proportion of the total family labor time available in period 2, T.

Assumption (v) implies that *leisure* is treated as a given fixed amount of time for the household. Leisure and consumption decisions are treated as separable here. This is done in order to highlight the tradeoffs of the household time allocation among the three alternatives, i.e., labor time is allocated to crops 1 and 2 and the residual is allocated to the off-farm labor market. One alternative to this assumption is to introduce *leisure* itself as a choice variable, but this would relax the labor time allocation problem for the household. In that case the household could expand or contract leisure hours in order to accommodate a change in the allocation of labor time in a particular alternative, without enforcing a tradeoff among the three (abovementioned) alternatives[2].

The regularity conditions needed to avoid non-meaningful results later on are:

(a) *positive crop prices.* $p_1 > 0$ and $p_2 > 0$ and

(b) *nonnegative period 2 wage.* $W_K = \overline{w_k} + (1 - d_k)\gamma \geq 0$.

The testable hypothesis of this study is that *cultivator households' expectations regarding the off-farm labor market at a later period influence its crop choice decisions*. Under the testable hypothesis, unfavorable expectations regarding the off-farm labor market at a later period would cause the households' *ex ante* crop choice decisions to move in one particular direction, that the household would allocate more of its land to less risky but less profitable crops. Expectation of a lower depth of the off-farm labor market and a lower wage rate in that market in the second period would cause the household to take less risk in its crop choice decisions and opt for a less risky portfolio. Therefore, building on the testable hypothesis, the model has two particular focus questions,

(1) $\partial k / \partial d_k < 0$?

(2) $\partial k / \partial \overline{w_k} < 0$?

[2] Maitra (2001, pp. 733) finds that the small farmers in the ICRISAT villages in India smooth consumption not at the cost of volatile leisure, but by making compensating changes in labor market participation.

The extension of the basic two period model, discussed in Section III.B, allows for one risk-mitigating factor on behalf of the household. This is the household share of irrigated land. In the presence of this risk-mitigating factor, the household is expected to act as more risk-taking in its approach to crop choices. Therefore it can be proposed that a higher share of irrigated land (denoted by a) would cause the household land share allocated to the less risky crops to fall. So there is one more focus question for the extended model,

(3) $\partial k / \partial a < 0$?

III.A.3. Maximization Problem

The households' crop income and off-farm labor income in period 2 are,

$$\text{Crop income} \equiv p_1Q_1 + p_2 Q_2$$
$$= p_1[f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\gamma]$$
$$+ p_2 [f^{(2)}(1 - k, L_2) + h^{(2)}(1 - k, L_2)\gamma]$$

$$\text{Off-farm labor income} \equiv [\overline{w_k} + (1 - d_k)\gamma] [T - L_1 - L_2]$$

The household total income from crop production and off-farm labor supply is

$$I = p_1[f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\gamma] + p_2 [f^{(2)}(1 - k, L_2) + h^{(2)}(1 - k, L_2)\gamma]$$
$$+ [\overline{w_k} + (1 - d_k)\gamma] [T - L_1 - L_2] \quad (3.1)$$

The household is assumed to use a two period dynamic programming algorithm to solve the maximization problem (Intriligator 1971). It solves a conditional second period problem first, choosing the optimal allocation of labor between on-farm crop production and off-farm labor supply conditional on its choice of value of the land allocation term (k) in the first period and realization of rainfall uncertainty. Then it solves the first period problem, choosing the optimal value for the land allocation term conditional on the responses of labor allocation in the second period to the choice of value of the land allocation term (k) in the first period and realization of rainfall uncertainty.

III.A.4. The Second Period Problem

Following the backward induction logic (Section III.A.3), I concentrate on the second period problem first. At the start of period 2, t_2, the rainfall uncertainty γ is resolved and value for the land allocation term k has already been determined. Since there is no uncertainty at this point, the problem now is a simple maximization problem conditional on the known realization of uncertainty and optimal decision taken in the previous period. Let γ be the realized rainfall shock, resolved on or before time t_2, and k^* be the optimal value of land allocation term determined at time t_1.

At time t_2 the problem stands at

$$\begin{aligned}\underset{L_1,\,L_2}{\text{Max}}\ I = \ & p_1[f^{(1)}(k^*, L_1) + h^{(1)}(k^*, L_1)\gamma] \\ & + p_2[f^{(2)}(1-k^*, L_2) + h^{(2)}(1-k^*, L_2)\gamma] \\ & + [\overline{w_k} + (1-d_k)\gamma]\,[T - L_1 - L_2] \end{aligned} \qquad (3.2)$$

The first order conditions for the second period problem are,

With respect to L_1,

$$\partial I/\partial L_1 = p_1[\partial f^{(1)}(.)/\partial L_1 + [\partial h^{(1)}(.)/\partial L_1]\gamma] - [\overline{w_k} + (1-d_k)\gamma] = 0 \qquad (3.3)$$

implies $p_1[\partial f^{(1)}(.)/\partial L_1 + [\partial h^{(1)}(.)/\partial L_1]\gamma] = [\overline{w_k} + (1-d_k)\gamma]$

that is, [value of marginal product of labor to crop 1] =

[opportunity cost of labor in the off-farm labor market].

With respect to L_2,

$$\partial I / \partial L_2 = p_2 [\partial f^{(2)}(.)/\partial L_2 + [\partial h^{(2)}(.)/\partial L_2]\gamma] - [\overline{w_k} + (1 - d_k)\gamma] = 0 \qquad (3.4)$$

implies $p_2 [\partial f^{(2)}(.)/\partial L_2 + [\partial h^{(2)}(.)/\partial L_2]\gamma] = [\overline{w_k} + (1 - d_k)\gamma]$

that is, [value of marginal product of labor to crop 2] =

[opportunity cost of labor in the off-farm labor market].

The second order conditions for the second period problem are,

With respect to L_1,

$$\partial^2 I / \partial L_1^2 = p_1 [\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma] < 0 \qquad (3.5)$$

With respect to L_2,

$$\partial^2 I / \partial L_2^2 = p_2 [\partial^2 f^{(2)}(.)/\partial L_2^2 + [\partial^2 h^{(2)}(.)/\partial L_2^2]\gamma] < 0 \qquad (3.6)$$

The second order cross partial derivative terms are (derived from (3.3) or (3.4)),

$$\partial^2 I / \partial L_1 \partial L_2 = \partial I^2 / \partial L_2 \partial L_1 = 0. \qquad (3.7)$$

In expression (3.5) both of the terms $\partial^2 f^{(1)}(.)/\partial L_1^2$ and $\partial^2 h^{(1)}(.)/\partial L_1^2$ are negative from the properties of the deterministic component of the production function and assumptions regarding the nature of its stochastic component as proposed in the discussion. Expression (3.5) needs to be negative in order for the second order condition to hold, but this expression can still be negative with a negative $\partial^2 f^{(1)}(.)/\partial L_1^2$ outweighing a positive term of $[\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma$. Therefore it is possible that the stochastic component of the production function can be *convex* instead of being *strictly concave* and still the second order condition for the second period problem to hold. This implies that the stochastic component can show *convexity* as well as *concavity*, but in order for the second period condition to hold, it is necessary that the negative second partial derivative of the deterministic component with respect to the inputs outweigh the second partial derivative of the stochastic component with respect to the same inputs. In other words, in order for the second order condition to hold, the input's marginal contribution to the mean productivity must decrease faster than the input's marginal contribution to the variance component of output (Feder 1980, pp. 267-268). The same argument holds for the second order condition for crop 2 in expression (3.6).

The other second order condition of the second period problem is also shown to be satisfied,

$[\partial^2 I / \partial L_1^2]\,[\partial^2 I / \partial L_2^2] - [\partial^2 I / \partial L_1 \partial L_2]^2 > 0,$

since $[\partial^2 I / \partial L_1^2] < 0$ (from (3.5)), $[\partial^2 I / \partial L_2^2] < 0$ (from (3.6)) and $[\partial^2 I / \partial L_1 \partial L_2] = 0$ (from (3.7)).

III.A.5. The Second Period Problem: Special Cases

I concentrate on some special cases of the second period problem in this section. The cases correspond to particular values that the rainfall shock term can obtain. Three cases discussed here correspond to the cases of zero, negative and positive rainfall shocks respectively.

Case 1. Zero Rainfall Shock, γ=0.

From the FOC for L_1, $\partial f^{(1)}(.)/\partial L_1 = p_1^{-1} \overline{w_k}$.

From the FOC for L_2, $\partial f^{(2)}(.)/\partial L_2 = p_2^{-1} \overline{w_k}$.

In the case of zero rainfall shock the household's optimal level of on-farm labor demanded in period 2 equates the value of marginal product of labor on-farm with the off-farm labor market real wage rate. The adjustment terms in the marginal product of labor equation due to the realization of the rainfall shock, such as $[p_1^{-1}(1- d_k)\gamma - p_1^{-1}[\partial h^{(1)}(.)/\partial L_1]\gamma]$

[following equation (3.3) and (3.4)] drop out. At zero rainfall shocks, the higher (lower) the real wage rate in the market, the higher (lower) the marginal productivity of labor, and therefore the lower (higher) the on-farm labor demanded for crops in period 2 (Figure 5).

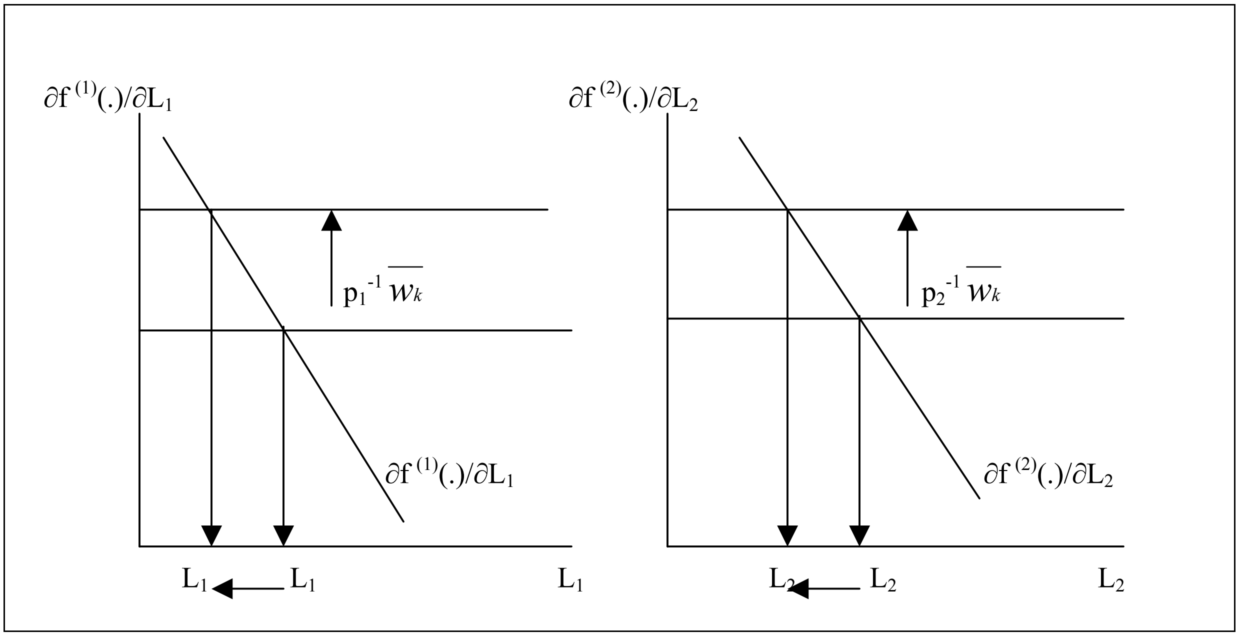

Figure 5. Decreases in the Optimal On-farm Labor, Period 2 in Response to an Increase in Real Wage in the Off-farm Labor Market (At Zero Rainfall Shock)

Case 2. Negative Rainfall Shock, γ<0.

From the FOC for L_1, $\partial f^{(1)}(.)/\partial L_1 = p_1^{-1}[\overline{w_k} + (1-d_k)\gamma] - [\partial h^{(1)}(.)/\partial L_1]\gamma$.

From the FOC for L_2, $\partial f^{(2)}(.)/\partial L_2 = p_2^{-1}[\overline{w_k} + (1-d_k)\gamma] - [\partial h^{(2)}(.)/\partial L_2]\gamma$.

In the case of L_1, the difference in the marginal productivities of period 2 labor under a negative rainfall shock and that under a zero rainfall shock,

$[\partial f^{(1)}(.)/\partial L_1]_{\gamma<0} - [\partial f^{(1)}(.)/\partial L_1]_{\gamma=0} = p_1^{-1}(1-d_k)\gamma - [\partial h^{(1)}(.)/\partial L_1]\gamma$.

For a negative rainfall shock, $\gamma<0$, the first term on the right hand side $p_1^{-1}(1-d_k)\gamma$ is negative and the second term $[\partial h^{(1)}(.)/\partial L_1]\gamma$ is also negative, therefore the overall sign is positive if the negative first term is outweighed by the positive second term, again the sign is negative if the first term dominates. The first term $p_1^{-1}(1 - d_k)\gamma$ is a measure of the impact of the negative rainfall shocks on the wage rate in the off-farm labor market. On the other hand the second term $[\partial h^{(1)}(.)/\partial L_1]\gamma$ is a measure of the impact of the same rainfall shocks on the variability of returns from crop 1 production. Since rainfall shocks affect both variability of on-farm crop productions and wages in the off-farm labor markets, whether negative rainfall shocks will cause period 2 on-farm labor demanded for crops to decrease or increase will depend on the relative strengths of the two impacts. If a negative rainfall shock has a weaker impact on the wage rate in the labor market than on the variability of returns from own farm production, less labor will be demanded on farm in period 2 as a response.

Case 3. Positive Rainfall Shock, γ>0.

From FOC for L_1, $\partial f^{(1)}(.)/\partial L_1 = p_1^{-1}[\overline{w_k} + (1 - d_k)\gamma] - [\partial h^{(1)}(.)/\partial L_1]\gamma$.

From FOC for L_2, $\partial f^{(2)}(.)/\partial L_2 = p_2^{-1}[\overline{w_k} + (1 - d_k)\gamma] - [\partial h^{(2)}(.)/\partial L_2]\gamma$.

In the case of L_1,

$[\partial f^{(1)}(.)/\partial L_1]_{\gamma>0} - [\partial f^{(1)}(.)/\partial L_1]_{\gamma=0} = p_1^{-1}(1 - d_k)\gamma - [\partial h^{(1)}(.)/\partial L_1]\gamma$.

Under positive rainfall shocks, $\gamma>0$, the second term $[\partial h^{(1)}(.)/\partial L_1]\gamma$ which is the impact of the rainfall shock on the variability of crop returns is positive and the first term $p_1^{-1}(1 - d_k)\gamma$ is also positive. The overall sign of the difference of marginal productivities of period 2 labor under a positive and a zero rainfall shock is therefore positive if the first term outweighs the second term and negative if the second term outweighs the first term. More labor will be demanded on-farm in period 2 as a response to positive shocks in rainfall if the impacts of rainfall shocks on the variability of crop returns outweigh their impacts on the wage rates in the off-farm labor market.

III.A.6. The Second Period Problem: Comparative Statics

I concentrate on some comparative static results of the second period problem in this section. The objective of this exercise is to analyze changes in the optimal allocation of on-farm labor in period 2 due to changes in exogenous variables such as wage and unemployment rates in the off-farm labor market as well as prices of crops, shock terms such as rainfall, and optimal choices of the previous period such as the value for the land allocation term.

Case 1. Effect of changes in $\overline{w_k}$ on the optimal values of L_1 and L_2.

Totally differentiating equation (3.3) with respect to L_1 and $\overline{w_k}$ one gets

$\partial L_1 / \partial \overline{w_k} = 1 / \{ p_1[\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma]\}$

Since the denominator term is negative from the second order condition of the second period problem,

$\partial L_1 / \partial \overline{w_k} < 0.$

Similarly totally differentiating equation (3.4) with respect to L_2 and $\overline{w_k}$, it can be shown that,

$\partial L_2 / \partial \overline{w_k} < 0.$

As second period off-farm labor supply is the residual of a given total family labor time in that period over on-farm family labor time applied to the crops,

∂(off-farm labor supply)/ $\partial \overline{w_k} > 0$.

A higher wage rate in the off-farm labor market pulls away labor from own crop production and increases off-farm labor supply by the household, while a lower wage rate has the opposite impact, both of these cases are conditional on the realized rainfall shock and planting period choice of value for the land allocation term.

Case 2. Effect of changes in d_k on the optimal values of L_1 and L_2.

Totally differentiating equation (3.3) with respect to L_1 and d_k one gets

$\partial L_1 / \partial d_k = -\gamma / \{ p_1[\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma]\}$

For negative rainfall shocks $\gamma<0$ the numerator is positive and the denominator is negative by the second-order condition of the second period problem, while for positive rainfall shocks $\gamma>0$ the numerator is negative and the denominator is also negative. Therefore

$\partial L_1 / \partial d_k < 0$ (for negative rainfall shocks $\gamma<0$), and

$\partial L_1 / \partial d_k > 0$ (for positive rainfall shocks $\gamma>0$).

Similarly totally differentiating equation (3.4) with respect to L_2 and d_k one can show that,

$\partial L_2 / \partial d_k < 0$ (for negative rainfall shocks $\gamma<0$), and

$\partial L_2 / \partial d_k > 0$ (for positive rainfall shocks $\gamma>0$).

Since off-farm labor supply is a residual labor time in excess of crop labor application time,

∂(off-farm labor supply)/ $\partial d_k > 0$ (for negative rainfall shocks $\gamma<0$), and

∂(off-farm labor supply)/ $\partial d_k < 0$ (for positive rainfall shocks $\gamma>0$).

In the case of negative rainfall shocks, a higher depth of the off-farm labor market would decrease on-farm labor allocation in period 2 and increase off-farm labor supply by the household. A lower depth of the market would on the other hand increase on-farm labor allocation to both of the crops and decrease off-farm labor supply, conditional on the realized rainfall shock and planting period choice of value for the land allocation term.

Case 3. Effect of changes in p_1 and p_2 on the optimal values of L_1 and L_2.

Totally differentiating equation (3.3) with respect to L_1 and p_1 one gets

$$\partial L_1/\partial p_1 = -\{[\partial f^{(1)}(.)/\partial L_1 + [\partial h^{(1)}(.)/\partial L_1]\gamma]\} / \{p_1[\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma]\}$$

Since the term in the numerator is negative and the denominator is positive, $\partial L_1/\partial p_1 > 0$.

Similarly, totally differentiating equation (3.4) with respect to L_2 and p_2 one gets $\partial L_2/\partial p_2 > 0$.

The off-farm labor supply will be negatively affected by a rise in p_1 and/or p_2,

∂(off-farm labor supply)/ $\partial p_1 < 0$, and

∂(off-farm labor supply)/ $\partial p_2 < 0$.

An increase in the expected harvest period price of a crop would increase household on-farm labor allocation to that particular crop and reduce off-farm labor supply by the household, conditional on the realized rainfall shock and planting period choice of value for the land allocation term.

Case 4. Effect of changes in γ on the optimal values of L_1 and L_2.

Totally differentiating equation (3.3) with respect to L_1 and γ one gets

$$\partial L_1/\partial\gamma = \{(1-d_k) - p_1[\partial h^{(1)}(.)/\partial L_1]\} / \{p_1[\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\gamma]\}.$$

The first term in the numerator $(1-d_k)$ is nonnegative, the second term $p_1[\partial h^{(1)}(.)/\partial L_1]$ is positive. The denominator is negative from the second order condition of the second period problem. This implies that the sign of the term $\partial L_1/\partial\gamma$ depends on the sign of the numerator term. If $(1-d_k) > p_1[\partial h^{(1)}(.)/\partial L_1]$ then the numerator is positive and the sign of the term $\partial L_1/\partial\gamma$ is negative. On the other hand if $(1-d_k) < p_1[\partial h^{(1)}(.)/\partial L_1]$ then the numerator term is negative and the sign of the term $\partial L_1/\partial\gamma$ is positive. Since the rainfall uncertainty term is entering into both variability in on-farm crop production and off-farm labor market the impact of realizations of rainfall shocks on on-farm labor demanded for harvest period crops depends on the signs of the terms from both of the operations.

Similarly totally differentiating equation (3.4) with respect to L_2 and γ one gets

$$\partial L_2/\partial\gamma = \{(1-d_k) - p_2[\partial h^{(2)}(.)/\partial L_2]\} / \{ p_2[\partial^2 f^{(2)}(.)/\partial L_2^2 + [\partial^2 h^{(2)}(.)/\partial L_2^2]\gamma]\}.$$

The sign of this expression $\partial L_2/\partial\gamma$ is negative if $(1-d_k) < p_2[\partial h^{(2)}(.)/\partial L_2]$ and it is positive if $(1-d_k) > p_2[\partial h^{(2)}(.)/\partial L_2]$.

The sign of the term ∂(off-farm labor supply)/∂γ will therefore be positive if $(1-d_k) < p_1[\partial h^{(1)}(.)/\partial L_1]$ and $(1-d_k) < p_2[\partial h^{(2)}(.)/\partial L_2]$ and negative if $(1-d_k) > p_1[\partial h^{(1)}(.)/\partial L_1]$ and $(1-d_k) > p_2[\partial h^{(2)}(.)/\partial L_2]$.

Case 5. Effect of changes in the planting period optimal decision k on the optimal values of L_1 and L_2.

Totally differentiating equation (3.3) with respect to L_1 and k one gets

$$\partial L_1/\partial k = \{\partial^2 f^{(1)}(.)/\partial L_1 \partial k + [\partial^2 h^{(1)}(.)/\partial L_1 \partial k]\,\gamma\}/$$
$$-\{\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\,\gamma\} \qquad (3.8)$$

The terms in the numerator $\partial^2 f^{(1)}(.)/\partial L_1 \partial k$ and $\partial^2 h^{(1)}(.)/\partial L_1 \partial k$ are positive by their specifications (Section III.A.2). In order for the numerator term to be always positive, the positive first term $\partial^2 f^{(1)}(.)/\partial L_1 \partial k$ must always outweigh the second term $[\partial^2 h^{(1)}(.)/\partial L_1 \partial k]\gamma$, even in case the later term turns out to be negative under negative rainfall shocks $\gamma<0$. This requirement is similar to the requirement in the case of the second order condition of the second period problem. The term inside the bracket in the denominator is negative following the second order condition of the second period problem. Therefore the sign of the term the term $\partial L_1/\partial k$ is positive.

Similarly totally differentiating equation (3.4) with respect to L_2 and $(1 - k)$ one gets

$$\partial L_2/\partial(1-k) = \{\partial^2 f^{(2)}(.)/\partial L_2 \partial(1-k) + [\partial^2 h^{(2)}(.)/\partial L_2 \partial(1-k)]\gamma\}/$$
$$-\{\partial^2 f^{(2)}(.)/\partial L_2^2 + [\partial^2 h^{(2)}(.)/\partial L_2^2]\gamma\}. \qquad (3.9)$$

This term is also positive following properties of the production functions.

Since off-farm labor supply is a residual of a given total family labor time over and above labor applications to crops 1 and 2, and since an increase in k will increase the on-farm labor allocated to crop 1 but that will also reduce $(1- k)$ which will act to reduce the on-farm labor allocated to crop 2, the sign of ∂(off-farm labor supply)/∂k can not be ascertained *a priori*.

Therefore a higher allocation of land for a crop at the start of the planting period will increase the on-farm harvest period labor demanded for the crop, but the overall effect on off-farm labor supply at harvest period will depend on the sum of changes in harvest period labor demanded for both of the crops.

III.A.7. The First Period Problem

At time t_1, the household chooses k to maximize expected utility of income E $\{U(I)\}$. The household's choice of k is conditioned on the responses of the second period labor allocation L_1 and L_2 to the choice of k in the first period and realization of rainfall uncertainty. At time t_1, the households' maximization problem is given by,

$$\begin{aligned} \max_{k} E\{U(I)\} = E\ U\{ & p_1[f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\gamma] \\ & + p_2[f^{(2)}(1-k, L_2) + h^{(2)}(1-k, L_2)\gamma] \\ & + [\overline{w_k} + (1-d_k)\gamma][T - L_1 - L_2]\} \end{aligned} \tag{3.10}$$

The first order condition for the first period problem,

With respect to k,

$$\begin{aligned} E\ [U'\{I\}\{ & \{p_1[\partial f^{(1)}(.)/\partial k + \partial h^{(1)}(.)/\partial k\,\gamma] - p_2[\partial f^{(2)}(.)/\partial(1-k) + \partial h^{(2)}(.)/\partial(1-k)\gamma]\} \\ & + \{p_1[\partial f^{(1)}(.)/\partial L_1 + [\partial h^{(1)}(.)/\partial L_1]\gamma] - [\overline{w_k} + (1-d_k)\gamma]\}\partial L_1/\partial k \\ & - \{p_2[\partial f^{(2)}(.)/\partial L_2 + [\partial h^{(2)}(.)/\partial L_2]\gamma] - [\overline{w_k} + (1-d_k)\gamma]\}\partial L_2/\partial(1-k)\}] = 0 \end{aligned} \tag{3.11}$$

It is to be noted that the effects from the second period responses to the first period choice, i.e., the second and third part of equation (3.11), are zero from equation (3.3) and (3.4) (the envelope theorem). Thus the first order condition for the first period problem in equation (3.11) can be rewritten as,

$$E\ [U'\{I\}\{p_1[\partial f^{(1)}(\ .)/\partial k + \partial h^{(1)}(\ .)/\partial k\ \gamma\ ] - p_2\ [\partial f^{(2)}(\ .)/\partial(1-k) + \partial h^{(2)}(\ .)/\partial(1-k)\gamma\ ]\}] = 0 \tag{3.12}$$

The second order condition requires that the total differential of equation (3.12) be negative,

$$\begin{aligned}
&E\ [U''\{I\}\{p_1[\partial f^{(1)}(\ .)/\partial k + \partial h^{(1)}(\ .)/\partial k\ \gamma\ ] - p_2\ [\partial f^{(2)}(\ .)/\partial(1-k) + \partial h^{(2)}(\ .)/\partial(1-k)\gamma\ ]\}^2] \\
&+ E\ [U'\{I\}\ \{\ p_1[\partial^2 f^{(1)}(\ .)/\partial k^2 + \partial^2 f^{(1)}(\ .)/\partial k\partial L_1{*}\partial L_1/\partial k] \\
&\qquad + p_1[\partial^2 h^{(1)}(\ .)/\partial k^2 + \partial^2 h^{(1)}(\ .)/\partial k\partial L_1{*}\partial L_1/\partial k]\gamma \\
&\qquad + p_2[\partial^2 f^{(2)}(\ .)/\partial(1-k)^2 + \partial^2 f^{(2)}(\ .)/\partial(1-k)\partial L_2{*}\partial L_2/\partial(1-k)] \\
&\qquad + p_2[\partial^2 h^{(2)}(\ .)/\partial(1-k)^2 + \partial^2 h^{(2)}(\ .)/\partial(1-k)\partial L_2{*}\partial L_2/\partial(1-k)]\gamma\ \}] < 0
\end{aligned} \tag{3.13}$$

The first term in the inequality (3.13) is negative since $U''\{I\}<0$ everywhere and the rest is a squared term. Therefore in order to show that the inequality holds one would need to show that the second term in that expression is negative as well.

The first term of the second expression is

$$[\partial^2 f^{(1)}(\ .)/\partial k^2 + \partial^2 f^{(1)}(\ .)/\partial k\partial L_1{*}\partial L_1/\partial k].$$

Substituting the expression for $\partial L_1/\partial k$ in equation (3.8), one gets

$$\begin{aligned}
&[\partial^2 f^{(1)}(\ .)/\partial k^2 \\
&+ \partial^2 f^{(1)}(\ .)/\partial k\partial L_1{*}\{\ \partial^2 f^{(1)}(.)/\partial L_1\partial k + [\partial^2 h^{(1)}(.)/\partial L_1\partial k]\ \gamma\ \}/ \\
&\qquad\qquad - \{\ \partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\ \gamma\ \}].
\end{aligned}$$

This expression is difficult to sign, but at the expected value of the rainfall shock $\gamma=0$ one can observe a definite sign, such as,

$$\partial^2 f^{(1)}(\ .)/\partial k^2 + \partial^2 f^{(1)}(\ .)/\partial k\partial L_1{*}[\{\ \partial^2 f^{(1)}(.)/\partial L_1\partial k\ \}/ - \{\ \partial^2 f^{(1)}(.)/\partial L_1^2\ \}]$$

which is the same as $\partial^2 f^{(1)}(\ .)/\partial k^2 - [\partial^2 f^{(1)}(\ .)/\partial k\partial L_1]^2\ /\ [\partial^2 f^{(1)}(.)/\partial L_1^2]$.

This last expression is negative from the strict concavity of the deterministic component of the production function. One can similarly show that the third term is also negative evaluated at the expected value of rainfall shock $\gamma=0$ (the second and the fourth term drop out at $\gamma=0$). Assuming the sign holds in the more general structure of the expressions, these terms are negative and since $U'\{I\}$ is positive everywhere, the second term in expression (3.12) is negative. Thus the second order condition in the first period problem holds.

III.A.8. The First Period Problem: Comparative Statics

Case 1. Effect of changes in d_k on the optimal values of k.

Totally differentiating equation (3.12) with respect to d_k and k one gets

$$\partial k/ \partial d_k = [\partial^2 E\ U'\{I\}/\partial k \partial d_k] / -[\partial^2 E\ U'\{I\}/\partial k^2]. \tag{3.14}$$

The denominator is expression (3.13). The numerator term is

$$E\ [U''\{I\}\{p_1[\partial f^{(1)}(.)/\partial k + \partial h^{(1)}(.)/\partial k\ \gamma] - p_2\ [\partial f^{(2)}(.)/\partial(1-k) + \partial h^{(2)}(.)/\partial(1-k)\gamma]\} \\ * \{[-\gamma][T - L_1 - L_2]]\}].$$

The term $U''\{I\}$ is negative for a risk-averse cultivator household, also the off-farm labor supply term $[T - L_1 - L_2]$ is nonnegative and γ is negative for negative rainfall shocks. In order to determine the sign of the numerator, one needs to determine the sign of the term $\{p_1[\partial f^{(1)}(.)/\partial k + \partial h^{(1)}(.)/\partial k\ \gamma] - p_2\ [\partial f^{(2)}(.)/\partial(1-k) + \partial h^{(2)}(.)/\partial(1- k)\gamma]\}$. This term is the *marginal return* for household from increasing the share of available land allocated to the low-mean and low-variance crop 1 (raising the value of k) at the expense of the share of available land allocated to high-mean and high-variance crop 2 (a lowered value of 1- k). Under expectation of a negative realization of rainfall shock $\gamma<0$, the risk averse cultivator household will raise the value of k if it finds this term to be positive, i.e., if the *marginal benefit* of raising the value of k outweighs the *marginal cost* of raising the value of k. The *marginal cost* of raising the value of k is to reallocate to a lower mean productivity of land, expressed by the term $[p_1\partial f^{(1)}(.)/\partial k - p_2\partial f^{(2)}(.)/\partial(1-k)]$, this is negative for the cultivator household since mean productivity of land is higher for crop 2 compared to the case of crop 1, assuming the exogenous price terms do not significantly alter the comparisons of returns for the two crops. On the other hand under expectation of negative realization of rainfall shock $\gamma<0$, the *marginal benefit* of raising the value of k is to reallocate to a lower marginal risk contribution of land use, expressed by the term $[p_1\partial h^{(1)}(.)/\partial k\gamma - p_2\partial h^{(2)}(.)/\partial(1-k)\gamma]$. Under $\gamma<0$, this term is positive for the cultivator household since marginal contribution to risk from land use is higher for crop 2 compared to the case of crop 1, assuming the exogenous price terms do not significantly alter the comparisons of risk contributions from the two crops. Therefore the term $\{p_1[\partial f^{(1)}(.)/\partial k + \partial h^{(1)}(.)/\partial k\gamma] - p_2[\partial f^{(2)}(.)/\partial(1-k) + \partial h^{(2)}(.)/\partial(1-k)\gamma]\}$ is positive under expectation of negative rainfall shock $\gamma<0$, provided the positive *marginal benefit* of raising the value of k from reduced marginal risk contribution from land use outweighs the negative *marginal cost* of raising the value of k from reduced mean productivity contribution from land use. This implies the abovementioned expression is positive under a negative rainfall shock. The denominator term is negative from the second order condition of the second period problem. Therefore,

$\partial k/\partial d_k \leq 0$, under a negative rainfall shock (focus question (1), Section III.A.2).

This implies that, under a negative rainfall shock, the expectation of a *higher* depth in the off-farm labor market in the harvesting period would tend to lead households to allocate *less* of its share of cultivable land to the crops with lower mean and lower variances of returns and *more* of its share of cultivable land to the crops with higher mean and higher variances of returns, and *vice versa,* holding all other things constant.

Case 2. Effect of changes in $\overline{w_k}$ on the optimal values of k.

Totally differentiating equation (3.12) with respect to $\overline{w_k}$ and k one gets

$$\partial k / \partial \overline{w_k} = [\partial^2 E\ U'\{I\}/\partial k\, \partial \overline{w_k}] \,/ -[\partial^2 E\ U'\{I\}/\partial k^2] \qquad (3.15)$$

The numerator term is

$$E\ [U''\{I\}\{p_1[\partial f^{(1)}(\,.)/\partial k + \partial h^{(1)}(\,.)/\partial k\,\gamma\,] - p_2\,[\partial f^{(2)}(\,.)/\partial(1-k) + \partial h^{(2)}(\,.)/\partial(1-k)\gamma\,]\}$$
$$*\ [T - L_1 - L_2]].$$

The numerator term is negative since $U''\{I\}$ is negative everywhere, the term $\{p_1[\partial f^{(1)}(.)/\partial k + \partial h^{(1)}(.)/\partial k\gamma] - p_2\,[\partial f^{(2)}(.)/\partial(1-k) + \partial h^{(2)}(.)/\partial(1-k)\gamma]\}$ is positive provided the positive *marginal benefit* from raising the value of k for the cultivator household outweighs the negative *marginal cost* of raising the value of k (discussion in Case 1, Section III.A.8) under expectation of negative rainfall shocks, the off-farm labor supply term $[T-L_1-L_2]$ is nonnegative from specifications. The denominator term $[\partial^2 E\ U'\{I\}/\partial k^2]$ is expression (3.13). Therefore,

$\partial k / \partial \overline{w_k} \leq 0$, under a negative rainfall shock (focus question (2), Section III.A.2).

This implies that, under a negative rainfall shock, the expectation of a *higher* wage rate in the off-farm labor market in the harvesting period would tend to lead households to allocate *less* of its share of cultivable land to the crops with lower mean and lower variances of returns and *more* of its share of cultivable land to the crops with higher mean and higher variances of returns, and *vice versa,* holding all other things constant.

III.B. The Two Period Model: Extensions

III.B.1. The Two Period Model Extensions: Maximization

The two period model constructed through Sections III.A.1 to III.A.8 is restrictive in the sense that households do not possess any instrument at their disposal to lessen the impacts of rainfall shocks. In the context of the study villages covered in the ICRISAT study in India, which is the area for empirical investigation in this study, this is a strong restriction on its own. The cultivator households do have some instruments at their disposal to counter the adverse effects of weather uncertainty. One of them needs special mention: *irrigation*. Irrigation is one important instrument directly at the cultivator households' disposal to counter adverse shocks of weather. The cultivator household with the full amount of its cultivable land irrigated would be secured from realizations of rainfall uncertainty through its impact on own crop production; it would still be subjected to realizations of rainfall uncertainty through its impact on the village off-farm labor market. Irrigation can be considered a choice variable for household in the long run-- whereas in the short run, this can be treated as given.

The two period model discussed earlier has been extended to take into account this instrument into the model structure; this makes the model more realistic but at the same time adds to its complexity. The instrument term, the household share of irrigated land, denoted by a, has been introduced in a multiplicative fashion with the rainfall uncertainty term γ-- this is due to the reason that household share of irrigated land is expected to directly reduce the immediate impact of rainfall shocks. The specifications for the "extended" model (in other words "modified") are as follows, Crop 1: $Q_1 = f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\,\gamma(1-a)$

Crop 2: $Q_2 = f^{(2)}(1-k, L_2) + h^{(2)}(1-k, L_2)\,\gamma(1-a)$

Wage in off-farm labor market at period 2: $W_K = \overline{w_k} + (1-d_k)\gamma$

Here

a=share of irrigated land out of total cultivable land of the cultivator household ($0 \leq a \leq 1$).

The first order conditions for the second period problem of the extended model are as follows.

With respect to L_1,

$\partial I/\partial L_1 = p_1[\partial f^{(1)}(.)/\partial L_1 + [\partial h^{(1)}(.)/\partial L_1]\,\gamma(1-a)] - [\overline{w_k} + (1-d_k)\gamma] = 0.$

With respect to L_2,

$\partial I/\partial L_2 = p_2[\partial f^{(2)}(.)/\partial L_2 + [\partial h^{(2)}(.)/\partial L_2]\,\gamma(1-a)] - [\overline{w_k} + (1-d_k)\gamma] = 0.$

The second order conditions for the second period problem of the extended model are as follows.

With respect to L_1,

$\partial^2 I/\partial L_1^2 = p_1[\partial^2 f^{(1)}(.)/\partial L_1^2 + [\partial^2 h^{(1)}(.)/\partial L_1^2]\,\gamma(1-a)] < 0.$

With respect to L_2,

$\partial^2 I/\partial L_2^2 = p_2[\partial^2 f^{(2)}(.)/\partial L_2^2 + [\partial^2 h^{(2)}(.)/\partial L_2^2]\,\gamma(1-a)] < 0.$

One special case of the first order conditions is to be mentioned here. That is the marginal products of second period labor allocation at a=1 and d_k =1,

$\partial f^{(1)}(.)/\partial L_1 = p_1^{-1}\,\overline{w_k}$ and

$\partial f^{(2)}(.)/\partial L_2 = p_2^{-1}\,\overline{w_k}$.

These are the same expressions as in the case of γ=0; rainfall uncertainty does not affect optimal choices of labor demanded in the second period at the point the village off-farm labor market is fully diversified ($d_k = 1$) and share of irrigated land for the cultivator household is unity (a=1). This implies that the cultivator household is fully protected from realizations of rainfall uncertainty only when both of the sources of impacts, such as own crop production and off-farm labor supply, have been protected by full irrigation and full diversity in the off-farm labor market.

The first order condition for the first period problem of the extended model is as follows.

With respect to k,

$$E\ [U'\{I\}\{p_1[\partial f^{(1)}(\,.)/\partial k + \partial h^{(1)}(\,.)/\partial k\gamma(1-a)]$$

$$- p_2\,[\partial f^{(2)}(\,.)/\partial(1-k) + \partial h^{(2)}(\,.)/\partial(1-k)\gamma(1-a)\,]\}] = 0. \qquad (3.16)$$

Here $I = p_1[f^{(1)}(k, L_1) + h^{(1)}(k, L_1)\gamma(1-a)]$

$$+ p_2\,[f^{(2)}(1-k, L_2) + h^{(2)}(1-k, L_2)\,\gamma(1-a)] + [\,\overline{w_k} + (1-d_k)\gamma]\,[T - L_1 - L_2].$$

The second order condition for the first period problem of the extended model requires that the total differential of equation (3.16) be negative:

$$E\ [U''\{I\}$$

$$*\{p_1[\partial f^{(1)}(\,.)/\partial k + \partial h^{(1)}(\,.)/\partial k\,\gamma(1-a)] - p_2\,[\partial f^{(2)}(\,.)/\partial(1-k) + \partial h^{(2)}(\,.)/\partial(1-k)\gamma(1-a)]\}^2]$$

$$+ E\ [U'\{I\}\{\,p_1[\partial^2 f^{(1)}(\,.)/\partial k^2 + \partial^2 f^{(1)}(\,.)/\partial k\partial L_1 * \partial L_1/\partial k]$$

$$+ p_1[\partial^2 h^{(1)}(\,.)/\partial k^2 + \partial^2 h^{(1)}(\,.)/\partial k\partial L_1 * \partial L_1/\partial k]\gamma(1-a)$$

$$+ p_2[\partial^2 f^{(2)}(\,.)/\partial(1-k)^2 + \partial^2 f^{(2)}(\,.)/\partial(1-k)\partial L_2 * \partial L_2/\partial(1-k)]$$

$$+ p_2[\partial^2 h^{(2)}(\,.)/\partial(1-k)^2 + \partial^2 h^{(2)}(\,.)/\partial(1-k)\partial L_2 * \partial L_2/\partial(1-k)]\gamma(1-a)\}] < 0 \qquad (3.17)$$

III.B.2. The Two Period Model Extensions: Comparative Statics

In this extended model I am particularly interested in one comparative static result. That is $\partial k/\partial a_k$, the effect of changes in household share of irrigated land on the land allocation term k taken by the cultivator household. The objective of this exercise is to analyze household approaches to the land allocation problem given the presence of risk-mitigating factors in its production environment. One would expect a reduced urgency on behalf of the household to resort to costly *ex ante* risk-management strategies in the form of crop choice decisions if some risk-mitigating mechanisms are already in place.

Case 1. Effect of changes in a on the optimal values of k.

Totally differentiating equation (3.16) with respect to k and a one finds

$$\partial k/\partial a = [\partial^2 E\ U'\{I\}/\partial k \partial a] \,/ - [\partial^2 E\ U'\{I\}/\partial k^2] \tag{3.19}$$

The numerator term in equation (3.19) can be expressed as

$$\begin{aligned}
[\partial^2 E\ U'\{I\}/\partial k\partial a] = E\ [U''\{I\}* \\
\{p_1[\partial f^{(1)}(\,.)/\partial k + \partial h^{(1)}(\,.)/\partial k\gamma(1-a)] - p_2\,[\partial f^{(2)}(\,.)/\partial(1-k) + \partial h^{(2)}(\,.)/\partial(1-k)\gamma(1-a)]\} \\
* \{(-1)\,p_1 h^{(1)}(\,k, L_1)\gamma + (-1)p_2\,h^{(2)}(1-k, L_2)\gamma\}] \\
- E\ [U'\{I\}*\{\,p_1[\partial h^{(1)}(\,.)/\partial k]\gamma\ - p_2[\partial h^{(2)}(\,.)/\partial(1-k)]\gamma\,\}].
\end{aligned}$$

The term $U''\{I\}$ is negative everywhere, the term $\{(-1)p_1 h^{(1)}(\,k, L_1)\gamma + (-1)p_2\,h^{(2)}\,(1 - k, L_2)\gamma\}$ is positive under negative rainfall shocks $\gamma<0$, and the middle term can be shown to be positive following the discussion under negative rainfall shocks in Section III.A.8, Case 1. Therefore the first term in the expression is negative. In the second term, $\{p_1[\partial h^{(1)}(.)/\partial k]\gamma - p_2[\partial h^{(2)}(.)/\partial(1 - k)]\gamma\}$ can be shown to be positive under negative rainfall shocks following the discussion in the aforementioned case. Since $U'\{I\}$ is positive, the second term is therefore negative under negative rainfall shocks. This implies the numerator term [∂^2E U′{I}/$\partial k \partial$a] is negative. The denominator expression [∂^2E U′{I}/∂k^2] is negative from the discussion of the second order condition of the first period problem of the extended model. Therefore,

$\partial k/\partial a_k \leq 0$, under a negative rainfall shock (focus question (3), Section III.A.2).

This implies that, under a negative rainfall shock, a *higher* share of household irrigated land would tend to lead households to allocate *less* of its share of cultivable land to the crops with lower mean and lower variances of returns and *more* of its share of cultivable land to the crops with higher mean and higher variances of returns, and *vice versa,* holding all other things constant.

This concludes the discussion of the comparative statics results for the extended model. In this model, under expectation of negative rainfall shocks, household decision on allocation of land has been found to be responsive to the amount of risk-mitigating factors present in its production environment and as discussed in Section III.A, the decision has been found to be responsive to household expectations regarding wage rates in the village off-farm labor market and the depth of this market.

CHAPTER IV

DATA

For empirical investigation of this study I use data from the ICRISAT survey in the semi-arid areas of India. I use these data for the following reasons:

(a) This data set investigates a number of villages in a particular area of India, where weather uncertainty plays a major role in determining outcomes of agricultural operations. Since the objective of this study is to investigate the impacts on agricultural production decisions from uncertainties in the off-farm labor markets that can depend on weather shocks, it is advantageous to study an area where weather uncertainty plays a prominent role both in crop production and off-farm labor markets.

(b) This data set is a panel. Panel data is suited to study dynamics of adjustments by households over time. Spells of unemployment or income mobility are better studied with panels (Baltagi 2001, pp. 6). Another advantage of panel data is that it allows one to control for unobserved cross section heterogeneity (Wooldridge 2002, pp. 169).

(c) The study villages of the ICRISAT survey in India demonstrate a wide array of crop choices. Farmers are accustomed to choosing among different crops with different return characteristics, and no particular crop fully dominates the study villages. This wide array of choices distinguishes this data set from other data sets where a monoculture dominates.

(d) This data set contains a particularly rich record of off-farm labor income opportunities facing the cultivator households. The data set keeps a record not only of off-farm labor income but also of source characteristics of off-farm work, involuntary unemployment, wages and average working hours in that market by source characteristics and the amount of on-farm work done by the same households within the reference period.

IV.A. The ICRISAT Survey in India

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) initiated village-level longitudinal studies in three broad production regions of India's semi-arid tropics (SAT) in 1975 as part of its research program for studies in the SAT around the world. Other benchmark village sites were opened in the 1980s-- five in West Africa and two more in India. The objective of this research program was to develop and nurture a longitudinal microeconomic database to help formulate policy recommendations for agricultural development of the SAT regions. The SAT includes those tropical regions of the world where rainfall exceeds potential evaporation four to six months of the year; mean annual rainfall in the SAT is within the range of about 400 to 1200 mm (Walker and Ryan 1990, pp. 2).

Much of peninsular India is SAT, this includes large parts of the states of Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajashthan, Tamil Nadu and Uttar Pradesh, based on the definition of SAT in 1975 (aforementioned, pp. 2).

IV.B. Sampling Information and Data Collection

Walker and Ryan (1990, pp.2-3,11-17) provides a detailed account of the sample selection process for the ICRISAT survey in India. The sample for the survey was selected in four stages (Figure 6).

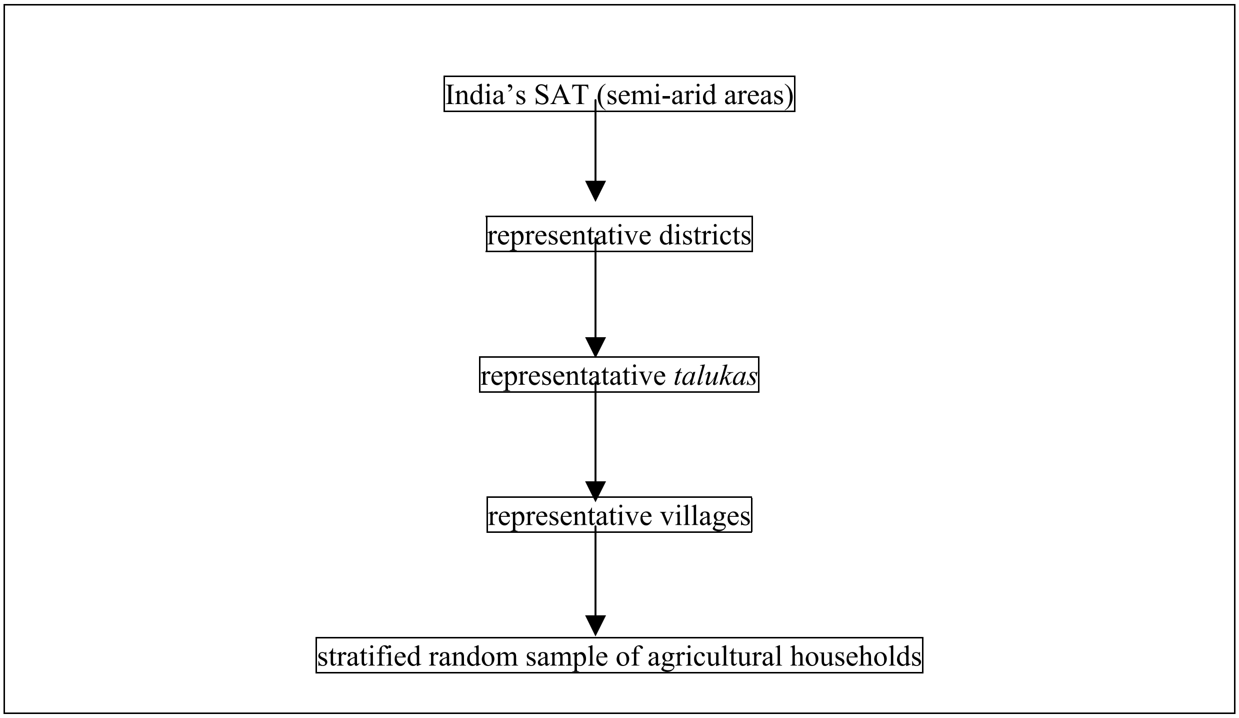

Figure 6. The Steps of Sample Selection of the ICRISAT Survey

First, the ICRISAT researchers identified districts that were representative of broad agroclimatic regions within India’s SAT. The districts were chosen based on rainfall data and soil and cropping criteria. Distance from the ICRISAT headquarters in Hyderabad, Andhra Pradesh and access to a nearby agricultural university or research station for logistical support was also taken into account in the selection of districts. The researchers identified three representative districts, (1) Mahbubnagar and the neighboring five districts (medium-deep Alfisols soil, annual average rainfall of 713 mm), (2) Sholapur and the neighboring three districts (medium-deep and deep Vertisols soil, annual average rainfall of 691 mm) and (3) Akola and the neighboring three districts (medium-deep Vertisols soil, annual average rainfall of 817 mm).

Second, the researchers identified representative *talukas* (smaller administrative units) within those districts. This was done with secondary data on about forty variables. The *talukas* that were most frequently characterized by values falling within the modal intervals of the forty variables were selected.

Third, the researchers identified representative villages within the *talukas* by visiting twelve to twenty villages in each selected *taluka*. Villages located near larger towns or on paved roads and those having special programs or direct access to outside resources such as private voluntary organizations were not selected. The scientists in state agricultural universities and officials in local government were consulted while selecting the representative villages. A total of six villages were finally selected. These were Aurepalle and Dokur in the Mahbubnagar region in the state of Andhra, Shirapur and Kalman in the Sholapur region in the state of Maharashtra, and Kanzara and Kinkheda in the Akola region in the state of Maharashtra.

Fourth, the researchers selected sample households within each of the selected villages. Taking into consideration the amount of data to be collected and the memory bias that is common in data with long periods between interviews, they decided to have a sample size of forty households from each of the villages. Each household in the study villages was primarily surveyed early in 1975, mainly on the size of operational landholding and occupation of the household. This census provided the basis for selection of sample households. The households not dependent heavily on agriculture, such as full-time village artisans, shopkeepers and traders were excluded from the sample. This eliminated only five percent of the total number of village households. After this elimination, a sample of thirty cultivator and ten landless labor households was drawn in each study village from the remaining population of interest. The cultivating households in each village were stratified according to operated farm size into three equally numerous groups. A random sample of ten households was drawn from each tercile. Landless labor households were defined as those operating less than half an acre (0.2 hectares) of land and whose main income came from earnings in the casual off-farm labor market in the village. A fixed sample size of cultivator and landless labor households in each village implied that the sampling fractions and relative farm sizes that demarcated the cultivator terciles varied from village to village (Table 1).

	Region (State)		
	Mahbubnagar (Andrha)	Sholapur (Maharashtra**)**	Akola (Mahrashtrha)
Village	Aurepalle	Shirapur	Kanzara
Household Population (N)[a]			
Laborers	146 (30.7)	97 (32.7)	54 (32.0)
Cultivators	322 (67.7)	183 (61.6)	109 (64.5)
Others	8 (1.7)	17 (5.7)	6 (3.6)
Total	476 (100)	297 (100)	169 (100)
Sampling fractions (%)[b]			
Laborers	6.8	10.3	18.5
Cultivators	9.3	16.4	27.5
Total	8.4	13.5	23.7
Farm Size (acre)			
Small	0.494-2.964	0.494-4.94	0.494-4.446
Medium	2.964-7.904	4.94-13.091	4.446-13.091
Large	>7.904	>13.091	>13.091

[a] based on 1975 Household Census
[b] percentage of village households in each group
Source: Walker and Ryan 1990, pp.13

Table 1. Household Population, Sampling Fractions and Relative Farm Sizes in the Study Villages

The key concept behind the data collection process was that of a *resident investigator*. From the beginning of the survey in April 1975 a resident investigator was placed in each of the six study villages. Each of the resident investigators had a university degree in agricultural economics, had a rural background and spoke the local language. His main responsibility was to collect and code data on the nine schedules of the survey (described in Section IV.C). Some data were collected at three-to-four week intervals; these were information on household transactions, labor and draft power utilization and crop cultivation by plot. Some other data were collected annually; these were information on the composition of the household, crops sown in particular plots at particular seasons, credit and debt, stocks, livestock, implements and machinery and farm buildings. The role of the resident investigator was that of a participant observer and a verifier based on auxiliary measurements aimed at improving reliability of the data collected. The resident investigators reported to senior staff, which visited the villages on a monthly basis in the early years and on a quarterly basis in the later years.

As forty households were selected from each of the six study villages, there were a total of 240 households at the start of the survey in 1975. Out of an initial 240 households, 24 left the panel during the period of the survey from 1975/76 to 1984/85. The majority of these 24 households permanently emigrated from the village and a number of heads of household died. As soon as a head of household retired from the panel, he or she was replaced by another household head chosen randomly from those in the same farm-size stratum based on the 1975 village census in that village. This way the sample size from six villages was maintained at 240 at any point in time from 1975/76 to 1984/85. The data for the nine schedules (described in the next section) were collected for the complete ten-year period for one village in each region; the villages were Aurepalle in the Mahbubnagar region, Shirapur in the Sholapur region and Kanzara in the Akola region. These three villages were referred to as “continuous” villages and the 104 households who stayed in the panel all throughout the entire survey period from these three villages belonged to the subsection of the data called “continuous” sample. For my empirical investigation I concentrate on this “continuous” sample subsection of the data set for completeness of information.

IV.C. The Structure of Data.

The data from the ICRISAT survey in India is composed of a total of nine schedules. Table 2 provides a brief description of these schedules.

Name of the Schedule	Focus	Records
		Common: identification such as card code, land class, household number, year, day of interview
C Files	Household Characteristics	Member code, sex, age, marital status, education, main and subsidiary occupations, remittances from members living outside village, attached laborer record, disability, status change in household, caste code etc.
EFG Files NP Files	General Endowment and Valuation	E: animal inventory F: farm implement inventory G: farm building records N: current (physical) stocks, sources of stocks and household annual requirements P: financial assets and liabilities (this includes credit information)
K Files	Labor, Draft Animal and Machinery Utilization	Migration and other reasons for not working, employment days, hours and wages in labor market, involuntary unemployment, work on own farm, other activities, structure of off-farm labor market etc.
Y Files PS Files	Plot Cultivation	Y: plot code, area of the plot, irrigated area, soil type, ownership status, value of land, revenue rate, season, operations, human labor and draft power use, inputs and machinery use, output unit and value. PS File: summary of the Y file information
L Files	Transaction Records	Household transactions: inflow and outflow
CE Price Files	Price	Village price information for Aurepalle, Shirapur and Kanzara
Rain	Rainfall Records	Rainfall record information for six villages including Aurepalle, Shirapur and Kanzara

Table 2. Structure of Schedules of Data from the ICRISAT Survey in India

IV.D. The Study Villages

This section provides a brief introduction to the sample villages of the current study. This section relies on Walker and Ryan (1990).

Infrastructure and Markets. All of the study villages were located within a few kilometers from a paved road. Daily bus services connected the villages with outside destinations. All the villages were electrified, but generally electricity was used for agricultural activities only. In each village there was a fair-price shop providing kerosene, sugar, rice or wheat at subsidized prices. There also were a large number of small private shops selling inexpensive consumer goods. The majority of villagers used to market their produce in nearby regulated markets, which received infrastructural support from the government. Most farmers used to rely on the auction system in those regulated markets and would sell their produce when they were cash constrained or they found the current regulated price to be profitable. They would generally store their agricultural produce and sell in a piecemeal fashion, except that they normally would not sell all of their crop produce of groundnuts immediately after harvesting. Farmers were found to be supply constrained on a number of occasions in terms of seed and fertilizer.

Soil Heterogeneity. Soil heterogeneity is widespread in the study villages. It is most evident in the Mahbubnagar region, which includes Aurepalle. In Aurepalle, farmers could classify village soils into five broad groups. Taking into account mixed and traditional soils and other characteristics, a total of twenty-one soil categories were recognized by the farmers of that village at the finest level of classification. The black-soil Sholapur and Akola regions did not have such a marked distinction of soil groups, as was the case in the Mahbubnagar region. Six major soil groups were classified by farmers in the Sholapur region (including Shirapur) and only three major soil groups were classified by farmers in the Akola region (including Kanzara).

Irrigation. Some particular long term trends of irrigation facilities emerged in the study villages, such as, (a) the area irrigated by groundwater was increasing, (b) surface irrigation from small catchments reservoirs called tanks was declining, and (c) electric pump sets were rapidly replacing animal-drawn and diesel-powered lifting devices. The well sinking and deepening accelerated in the study villages during the survey period, aided by subsidized electricity, rapid technological change in groundwater pumping and in lift irrigation, and cheap institutional credit. For example, agricultural wells in use increased by 25 percent in Aurepalle from 1974 to 1984 and by 1984 there were 190 wells inside the village boundaries; the number of electric pumpsets also grew from 75 to 136 in that village during that period. While in Aurepalle the finance for well digging came from village moneylenders, in the other two villages, Shirapur and Kanzara, well digging was financed by an increasingly easier access to institutional credit. Regarding ownership of wells, it can be noted that joint ownership of wells was common in Shirapur, less common in Aurepalle and rare in Kanzara-- among the active wells jointly or solely owned by respondent households in Aurepalle, Shirapur and Kanzara; the average number of owners per well were 4.8, 2.4 and 1.0, respectively. The cost of sinking wells was greater in Shirapur than in the other villages, providing incentives for entering into joint ventures in financing for sinking wells, particularly since farmers were confronted with an imperfect capital market.

Animal Draft Power. In all the three study villages, cultivation, including operations such as plowing, harrowing, and interculturing, was carried out with animal draft power, typically bullocks. Many sample households owned small amounts of cultivable land but did not own bullocks-- this was most pronounced in the village Shirapur. A seasonal market for bullock hiring was active in each of the villages, but this market was incomplete because of the synchronic timing of agricultural operations, which gave rise to a high incidence of covariate demand for hired bullock among farmers within the same village.

Agricultural Operations. The sequence of agricultural operations and crop calendar varied from region to region in the study villages. Most land in these villages was plowed before the onset of the monsoon season; plowing was carried out with wooden country plow, which was also used for sowing. In the Sholapur and Akola regions farmers would carry out a deeper plow every three to five years following the post-rainy season harvest, at the time when the soil was still soft enough to till. With the onset of the monsoon in June, farmers in Aurepalle planted their cereal crops as soon as sufficient soil moisture was accumulated to allow seedling emergence. Castor was planted later in June or in early July in Aurepalle. The cereals were harvested after the monsoon receded in October. There was strong competition for labor demanded for irrigated crops during July and October, when paddy was transplanted, weeded and harvested. In Shirapur frequent drought was a severe constraint to rainy season cropping, where the presence of deep, black soils enhanced the comparative attractiveness of post-rainy season cropping. In Shirapur farmers would usually plant more drought-tolerant crops, such as pigeon pea and pearl millet, on their fields with lighter soils during the rainy season while they would save their better fields (usually with deeper soils) for more certain post-rainy season cropping. Farming in Kanzara was less vulnerable during the monsoon period. Planting in Kanzara was usually over by the first week of July with the sowing of local sorghum, following the planting of cotton, hybrid sorghum, pigeon pea and other monsoon season crops in the third week of June. Farmers would weed, hoe, spray or dust pesticide and apply fertilizer in July and August. Mung bean was harvested in September, hybrid sorghum in October, cotton in November and early December and pigeon pea and local sorghum later in the month of December.

Cropping Patterns. Cropping patterns varied from region to region in the study villages. Row cultivation of at least two species in the same field during the same season was common, particularly in the more rain-assured village of Kanzara. Intercropping was common in the rainy season and rare in the post-rainy season when the incidence of terminal drought stress was high for all crops. A number of cropping systems were commonly grown by many of the farmers in each village, such as sorghum/pearl millet/pigeon pea intercrop, castor and paddy in Aurepalle, sorghum in Shirapur, various cotton intercrops in Kanzara (usually in a particular ratio of row intercropped cotton to pigeon pea and/or sorghum and/or mung bean). But in none of the villages did one particular cropping system completely dominate in a season-- usually none of the cropping systems would have more than half of cultivated land allocated to it alone in an agricultural season. The common cropping systems ranged from traditional, low-input intensive cropping systems such as rainy season cereal/pulse intercrop in Aurepalle to modern, high-input intensive cropping systems such as irrigated paddy in Aurepalle and hybrid sorghum and cotton/mung bean/pigeon pea intercrop in Kanzara. Low-input intensive cropping systems were characterized by a lower proportion of modern inputs per plot; for example, only 4 percent of all plots allocated to sorghum/pearl millet/pigeon pea intercrop in the village Aurepalle used fertilizer, 21 percent of the same plots used manure and 3 percent of the plots used pesticide (Walker and Ryan 1990, Table 3.2, pp. 48). On the other hand high-input intensive cropping systems were characterized by higher proportion of use of modern inputs per plot; for example, 78 percent of plots allocated to cotton/mung bean/pigeon pea intercrop in the village Kanzara used fertilizer, 32 percent of the same plots used manure and 29 percent of them used pesticide (aforementioned, pp. 48).

Village Labor Market. In all the study villages there were two components of labor market-- one was casual and the other one was long-term. The casual labor market consisted of a daily rated sub-market and a contracts and temporary migration sub-market. In the daily component of the casual labor market contracts were negotiated for a short period of time, usually a single day or at most a week and payments were made each day for an agreed number of hours. In the contract sub-market laborers were organized by an intermediary and were compensated for on a piece-rate basis for a specific job for other farmers or government agencies. The wage rates in the contract sub-market were generally higher than those in the daily casual labor market but the former typically required more intensive work or longer hours of work. On the other hand the long-term submarket consisted of two components-- regular farm servants and domestic servants. The regular farm servants were exclusively men and domestic servants comprised women and boys. The demand side of this long-term labor sub-market originated from the wealthier and usually larger households.

Daily Casual Labor Sub-Market. The major portion of labor income in the study villages was generated in the daily casual labor market. Walker and Ryan (1990, pp. 110) characterize the daily casual labor market as "impersonal" as they mention that patron-client relationships or linkages with the markets for land and credit were more of exceptions than the rule in this market. Similarly it was rare to find connections between contracts in this market with obligations towards lenders or landlords for credit or tenancy arrangements. The functioning of this section of labor market was simple-- in the evenings employers, regular farm servants or wives of the regular farm servants would search for candidates for work on the following day. In Sholapur region employers would search for more efficient and reliable workers first and offer them premiums. Workers who had to search for their potential employers generally would have had to accept work offers at a discounted rate. Employers were generally indifferent about caste or socioeconomic conditions of potential employees-- similarly caste did not play a role in employees' screening of potential employers. There was much flexibility about change of employers or employees. Employees were willing to work for almost any employer any time of the year and it was common for an employee to be engaged by more than twenty employers throughout the course of the year. The daily casual labor market was *segmented by gender*-- men and women both would perform only two operations in common such as harvesting and threshing. Women used to concentrate on five tasks, such as nursery bed raising, transplanting, planting, weeding and thinning. On the other hand men used to concentrate on nine tasks-- four of them involved bullock power (Walker and Ryan 1990, pp. 125). This labor market segregation by sex was also promoted by dominant views in the village society. For example, social taboos prohibited women from touching the plow and the society also ridiculed men who would do domestic chores. The village society viewed the segmentation between men's and women's tasks as ruled by *dharma*, or duty, related to the biological role of women in bearing children and the strength of men. Wage discrimination in the daily labor market against women was evident in all the villages[3]. Both cash and kind wages were commonly accepted in the study villages in the daily labor market. In both Shirapur and Kanzara daily labor was paid in cash while in the village Aurepalle this payment was in kind, mostly in paddy, sorghum or castor.

IV.E. Construction of Variables

This section deals with the construction of variable information. For each sub-section describing data work for particular variable information I proceed with the source of data, methods used in constructing the variables and, on a number of occasions, summary findings from work in that particular section of data.

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[3] Appendix 16 reports mean value for male real wage rate in rupees/hr is 0.794 (st. deviation 0.177) while the corresponding figure for female is 0.493 (st. deviation 0.117) in three study villages in 1979-1984 (N=467).

IV.E.1. Rainfall Information

Source. The source of rainfall information is the schedule "Rain" of the ICRISAT data set. The format of the data is in the order of village, day, month, year, days-since-Jan-1 and millimeters-of-rainfall.

Methods. From the rainfall information ten variables have been generated, in order to adequately capture "rainfall uncertainty" faced by the cultivator households, these are, monsoon onset date, monsoon end date, total monsoon rainfall, number of rainy days within monsoon, intraseasonal drought days within monsoon (period 1), intraseasonal drought days within monsoon (period 2), length of monsoon, fraction of days with rain within monsoon, average rain per day within monsoon and average rain per rainy day within monsoon. From these ten variables three classes of information have been generated, namely village-specific means of the variable (over the entire time period), village-specific standard deviations of the variable (over the entire time period) and village-specific yearly deviations of the variable (deviation from the village mean for that variable).

Since rainfall information for the village Aurepalle for 1975 starts only on August 26th of that particular year, rainfall information for 1975 for Aurepalle has been dropped for the reason of possible incomplete information. Therefore information for Aurepalle has been limited to the years from 1976 to 1986. For the two other villages, Shirapur and Kanzara, information is recorded from 1975 to 1986.

Monsoon onset date was determined following its definition by Rosenzweig and Binswanger (1993, pp.63). They propose the monsoon onset date to be specified at the point of "*the date after which there has been at least 20 mm of rain within several consecutive days after 1 June*." The monsoon end date is defined at the starting point of a large discontinuity in rainfall (in terms of days with rain) after a fairly regular spell of rainfall. Total monsoon rainfall is defined as the sum of rainfall within the period of onset date to end date of monsoon. Intraseasonal drought days (period 1) is defined as the largest number of consecutive days without rain within a monsoon season, whereas intraseasonal drought days (period 2) is the second largest number of consecutive days without rain. Fraction of days with rain is the number of days with rain (number of rainy days) divided by the total number of days (length of monsoon) within a monsoon season. Average rain per day is the total amount of rainfall divided by total number of days within a monsoon season, whereas average rain per rainy day is total amount of rainfall divided by total number of rainy days.

Summary Findings. Appendix 1 presents means and standard deviations for rainfall shock terms for the study villages. Mean values for a number of rainfall shock terms are higher for Kanzara whilst standard deviation terms are in general lower compared to the other two villages. This indicates Kanzara enjoyed a favorable production environment compared to the other two in terms of rainfall uncertainty.

IV.E.2. Consumer Price Index Information

Source. The source of consumer price index information for the three study villages are the state-level nonfood price indices taken from the Consumer Price Index for Agricultural Labor (CPIAL) compiled by the Directorate of Economics and Statistics (1982) for each state in India (Walker and Ryan 1990, pp. 67).

Methods. Since the CPIAL data is at state-level, one finds that the consumer price index information available for the study village Aurepalle is of the state in where it is located, which is the state of Andrha. Similarly, information available for the study villages

Shirapur and Kanzara is of the state in where they are located, which is the state of Maharashtra. The consumer price index information available for these two states is from 1975 to 1984 whereas 1983 is considered as the base year for comparison.

Summary Findings. Appendix 2 provides the table for the consumer price indices in the study villages. Since two of the villages are from the same state, the comparison here is between two state-level consumer price indices. The agricultural labor consumer price indices for the states of Andhra and Maharashtra during the period of 1975-1984 show strong positive correlation, the Pearson coefficient of correlation is 0.96282 and the null hypothesis of no linear correlation between them is rejected at the 1 percent significance level.

IV.E.3. Household Characteristics Information

Source. The source of household characteristics information is the schedule "C" in the ICRISAT data set.

Methods. I collect information on fourteen variables from this data set, in addition to information on caste rankings of the households (Singh, Walker and Jodha 1985, pp. 36-37). Here is a list of the fourteen demographic variables: household size, age of household head, a dummy for households headed by women, the number and average age of household males within the age range of 15 to 45, the number and average age of household females within the age range of 15 to 45, the sum of numbers of household males and females within the age range of 15 to 45, a dummy for households with at least one member within age range of 15 to 45, the education level of household head and that of household female principal member, a dummy for households of whose heads are not illiterate, the number of remittance members for the household and a dummy for households receiving remittance.

In calculating the household size in any year I excluded household members who were currently staying outside the village and full-time or part-time permanent servants who were currently staying in the households. The household size changed over time as members were moving in or out due to marriage, search for jobs, disintegration of joint family into smaller units or return home after a period of absence or due to birth or death of a member (aforementioned, pp. 35-36). The variables of number and age of male and female household members aged within the range of 15 to 45 is meant to measure households' ability to participate in the village off-farm labor market (Kochar 1999, pp. 57). A dummy variable is therefore constructed for the households who have at least one able-bodied male or female member within that age range. Education levels of the head and female head of the household were also recorded along with a related dummy variable for the households whose heads were not illiterate; the education levels were coded in the following order in the original data-illiterate (1), read and write (2), up to primary school (3), up to middle school (4), up to high school (5), diploma course (6), graduate degree (7), post-graduate degrees and above and (8) technical degrees such as medical, engineering or agriculture etc. (9) (Singh, Walker and Jodha 1985, pp. 29). The number of members who were staying outside and sending remittances was also recorded along with a dummy variable for the households receiving remittances in that particular year.

Summary Findings. Table 3 and Appendix 3 and 4 are summary findings of household characteristics information from the three study villages for the year 1979.

While Table 3 provides an overall summary from a total of 124 observations from these villages, Appendix 3 and 4 provides summary information by village and landholding class respectively.

Variable Name (N)	Overall Mean (*Standard Deviation*)	Min.	Max.
Household Size (N=124)	5.68 (*2.46*)	1	17
Age of Household Head (N=124)	48.44 (*11.03*)	24	76
Female Household Head (N=124) (Female=1, Male=0)	0.18 (*0.38*)	0	1
Number of Household Males (N=124) Within Age Range of 15 and 45	1.27 (*0.93*)	0	4
Number of Household Females (N=124) Within Age Range of 15 and 45	1.42 (*0.90*)	0	5
Sum of Numbers of Household Males and Females Within Age Range of 15 and 45 (N=124)	2.69 (*1.58*)	0	9
Households With At least One Male or Female (N=124) Within Age Range of 15 and 45 (Yes=1, No=0)	0.94 (*0.25*)	0	1
Average Age of Household Males (N=101) Within Age Range of 15 and 4	28.70 (*7.98*)	15	44
Average Age of Household Females (N=111) Within Age Range of 15 and 45	29.46 (*7.25*)	16	44
Education Level of Household Head (N=124) (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.79 (*1.25*)	1	7
Education Level of Principal Female Member (N=123) (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.35 (*0.84*)	1	4
Not Illiterate Household Head (N=124) (Illiterate=0, Otherwise=1)	0.35 (*0.48*)	0	1
Number of Remittance Members (N=124) Per Household	0.30 (*0.95*)	0	6
Household Receives Remittance (N=124) (Yes=1, No=0)	0.15 (*0.36*)	0	1
Caste Ranking (N=123)	5.28 (*3.95*)	1	20
Doherty Caste Ranking (N=123)	3.37 (*2.20*)	1	7
Behrman Caste Ranking (N=123)	49.81 (*27.68*)	1.25	97.5
J.G.Ryan Caste Ranking (N=123)	2.38 (*1.20*)	1	4

Table 3. Summary Statistics of the Sample Household Characteristics of the Study Villages in 1979

In the year 1979 the average size of the 124 sample households from the three villages stood at 5.68 (standard deviation 2.46); household sizes did not vary much by villages but they differed by landholding class-- landless labor households as a group had on average a household size of 4.66 while large farmers as a group had on average a household size of 6.52. The average age of household head stood at 48.44 (standard deviation 11.03)-- Aurepalle had on average older household heads (52.34) compared to Kanzara (44.88) while the corresponding number for Shirapur fell in between (48.02). Male members headed a clear majority of households since only 18 percent of them had female members as heads in 1979. Female principal members were found to be less educated than male heads of their households, the corresponding overall average were education levels of 1.35 and 1.79 respectively; this implies on average a sample household was headed by someone whose education level was somewhere in between the level of "illiteracy" and "to be able to read and write". While in the full sample illiterate males or females headed a total of 65 percent of the households, the incidence of illiteracy of household head was highest in Aurepalle (73 percent) and lowest in Kanzara (60 percent) and again highest among landless labor households (87 percent) and lowest among large households (35 percent). On average a sample household had 1.27 and 1.42 number of able-bodied males and females respectively falling within the age range of 15 and 45, the age range best suited to participate in the village off-farm labor market; these figures did not vary much by village but varied slightly in favor of large farmer households. Average age of household male and female members within the age range of 15 to 45 across the villages was around 27 to 30 and this did not differ much by village or landholding class. Only 15 percent of households across the villages received remittances and the incidence of remittance was higher among the large farmer households (32 percent) and lower among the small farmer households (3 percent)--again while on average there was 0.58 number of remittance members per household in Kanzara, the corresponding number of Shirapur was a much smaller figure of 0.14. A number of caste rankings are also reported, one of them is the ranking prepared by Jere R. Behrman; his was based on rank ordering of sample household castes, this system took into account the relative frequency with which households of different castes appeared in the sample (Singh, Binswanger and Jodha 1985, pp. 37). The ranking is between 0 and 99 and the average caste ranking across the villages stood at 49.81; landless labor households had on average a lower ranking of 34.17 while large farmers had on average a higher ranking of 72.70, indicating caste rankings in the sample villages might have been correlated with household wealth level.

IV.E.4. Household Assets

Source. The source of household assets information is the set of schedules "E," "F" and "G" in the ICRISAT data set. Schedule "E" records animal inventory information of the household, schedule "F" records household inventory for farm implements and schedule "G" records household inventory for farm buildings.

Methods. Three variables have been recorded from combining information from the abovementioned schedules, such as, valuation of total household non-financial assets, valuation of farm buildings owned by the household and valuation of household assets excluding farm buildings.

Total household non-financial assets as recorded here include durables and non-durables such as inventory of livestock, animal products, agricultural equipments, major farm machinery and equipments, fodder and fuel items, consumer durables and production capital. The category "farm buildings" includes the total value of land and structures owned by the household (total area covered by the courtyard, including residential house, animal shed, open area). Since this is a common item for almost all the households, this is considered for a separate variable as well, as an indicator of household wealth. The third variable excludes the valuation of farm buildings from total asset valuation.

Summary Findings. Appendix 5 presents summary statistics of the household non-financial valuation of assets information for the overall sample and by landholding class. The value of household non-financial assets in 1983 constant prices was increasing during the year 1979 to 1984 period with differences in averages by landholding classes.

IV.E.5. Crop Grouping

Source. The source of crop grouping information of the cultivator households is the "PS" schedule of ICRISAT data.

Methods. Since rainfall uncertainty is more prominent in case of the *kharif* (rainy) season crops I concentrate on dealing within information from the *kharif* season only. The objective here is to classify the *kharif* season crops into two distinguishable groups, such as a "high mean and high variance" group and a "low mean and low variance" group, on the basis of the crop returns and variability of returns records over time. From the "PS" schedule I have information of crop returns from all three villages for the years 1975 to 1984. I concentrate on two pieces of information that are reported in the "PS" schedule, these are "(crop) net income" and "(crop) net return." "Net income" from a plot of land in a season is calculated as total output value (the sum of main product value and byproduct value) minus total input value (the sum of values of seed, fertilizer, sheep penning, manure, tank, pesticides, family labor, hired labor, own bullock labor and hired bullock labor). On the other hand "net return" from a plot of land in a season is calculated in the same way except that it does not include values for family labor and own bullock labor. Thus while "net income" can be considered as "economic profits" from cultivation operations of a plot of land taking into account all costs incurred including own family labor and own bullock labor participation costs (this cost was calculated at current ongoing market wage rates by the ICRISAT researchers), "net return" can be considered as "accounting profits" from cultivating the same plot of land. I keep record of both of these measures of returns for the sake of comparison. While "net return" measures are more suited for discussions since they do not involve potentially arguable measurement and evaluation of family labor and bullock labor participation costs calculated by the ICRISAT researchers- "net income" measures can provide an indication of the true costs associated with crop production activities.

Here are the steps that have been taken to calculate mean net income and mean net return of the crops planted,

A. First I convert the "net income" and "net return" from crop return figures per plot for crops planted in the *kharif* season into 1983 constant prices.
B. Second I convert the net income and net return at 1983 constant prices per plot into "net income per acre" and "net return per acre" terms.
C. For one particular crop, one particular village, one particular year, I apply this formula:
   Net income= $\sum$ (plot area)(net income per acre from the plot)/ $\sum$ (plot area).

D. Next step, for one particular crop, one particular year (maximum number of villages 3):

Net income= ∑ (plot area from one village)(weighted average in C from that village)/ ∑ (plot area from one village).

E. Final step, for one particular crop (maximum number of years 10):

Net income= ∑ (plot area from one year)(weighted average in D from that year)/ ∑ (plot area from one year).

A similar formula is applied to calculate the mean net returns for each of the crops.

For measuring standard deviations of net income and those of net return for each of the crops, the following steps are taken,

F. First I convert the "net income" and "net return" per plot for crops into 1983 constant prices.

G. For one particular crop, one particular village, one particular year, I apply this formula:

Standard deviation of net income= squared root of

"∑ (net income per acre − weighted average of net income as in C)^2 / (N −1)"

where N is the number of observations.

H. Next step, for one particular crop, one particular year (maximum number of villages 3):

Standard deviation of net income=

∑ (plot area from one village)(weighted average of standard deviation of net income as in G from that village)/ ∑ (plot area from one village).

I. Final step, for one particular crop (maximum number of years:10):

∑ (plot area from one particular year)(weighted average of standard deviation of net income as in H from that year)/ ∑ (plot area from one particular year).

A similar formula is applied to calculate the standard deviation of net returns for each of the crops.

The abovementioned formula has been applied to calculate crop returns for a total of 31 crops that were listed as first crops in the plots planted in the study villages during 1975 to 1984. The crops that were planted in only one plot in a particular village in a particular year have been excluded because of small numbers of observations. Appendix 6 provides the results of crop return calculations, per acre and in 1983 constant prices. The returns are measured in four categories such as weighted average of net income, weighted average of net return, weighted average of standard deviation of net income and weighted average of standard deviation of net return. The measurements show statistically significant positive correlations between each other. For example, the Pearson coefficient of correlation between weighted average of net income and weighted average of net return is 0.99012 and that between weighted average of standard deviation of net income and weighted average of standard deviation of net return is 0.99754 (in both cases the null of no linear correlation is rejected at the 1% level). The measurement in terms of weighted average of net income is statistically significantly positively correlated with the measurement in terms of weighted average of standard deviation of net income; the Pearson correlation coefficient between them is 0.57821 and the null of no linear correlation is rejected at the 1% level. Similarly, the measurement in terms of weighted average of net return is statistically significantly positively correlated with that of weighted average of standard deviation of net return; the Pearson correlation coefficient between them is 0.65907 and the null of no linear correlation is rejected at the 1% level. These positive and statistically significant correlation coefficients between mean and standard deviation measurements imply that it is possible to classify the crops in the study villages in categories such as crops with "high means and high variances" and crops with "low means and low variances."

I rank the *kharif* season crops planted in the study villages in terms of the abovementioned return measurements in descending orders. Appendix 7 presents the rankings of 31 crops according to four measurements following their return characteristics in Appendix 6. Appendix 8 presents the classification of crops following their rankings in Appendix 7-- the crops for which all four of their return measurements showed rankings above or equal to 15 or 16 (upper half of the list) were placed in the "High" crop group category and the crops for which all four of their return measurements showed rankings below or equal to 15 or 16 (lower half of the list) were placed in the "Low" crop group category. A total of 29 crops were unambiguously classified this way while two crops maize (local) and blackgram (urad) were found to be ambiguous in terms of the abovementioned criterion-- their rankings in terms of weighted average of net income and net return differ greatly from their rankings in terms of standard deviation measurements. Comparing within these two crops maize (local) with higher standard deviation figures (with lower average return figures) has been placed in the "High" crop group while blackgram (urad) with lower standard deviation figures (with higher average return figures) is placed in the "Low" crop group (Appendix 8) since the first one can be considered riskier than the later one. This way a total of 16 crops have been placed in the "High" group while the remaining 15 crops have been placed in the "Low" group (Table 4).

The method that has been followed here to classify the crops concentrates on rankings in terms of mean returns and standard deviation of returns. An alternative specification could have been rankings of crops in terms of their coefficient of variations of returns. The selection of rankings therefore centers on one particular question that is *which one of these two is a better measurement of "risk"-- standard deviation or coefficient of variation?* Given the crop returns data at hand I argue that the rankings in terms of coefficients of variations can provide a flawed comparison of crops in terms of "risk". For example, a particular crop with a low mean of net return and low standard deviation of net return can have the same

Classification of Crops in terms of Return and Riskiness	Name of Crops	Total Number of Crops
High	Groundnuts Castor (HYV) Bajra/Pearl Millet (HYV) Jowar/Sorghum (HYV) Maize (Local) Paddy (Local) Paddy (HYV) Wheat (HYV) Cotton (Local) Cotton (HYV) Lemon Sugarcane Onion Chillies Other Vegetables Green Fodder Crops	16
Low	Sesamum Castor Sunflower Safflower Bajra/Pearl Millet (Local) Jowar/Sorghum (Local) Wheat (Local) Other Cereals Other Fruits Redgram (Tur)/Pigoen pea Greengram (Mung) Blackgram (Urad) Bengalgram (Chenna)/Chick pea Other Pulses Other Spices (Salt, Tamarind etc.)	15
Total		31

Table 4. Crop Grouping.

Fcoefficient of variation (ratio of standard deviation and mean) as another crop with a much higher average net return and a much higher standard deviation of net return (the ratios in both cases could be the same). A ranking of these two crops would then be the same in terms of *coefficients of variation* but the two crops actually would be much different in terms of their respective *riskiness*.

The crop classification (into the "low" crop group and the "high" crop group) as discussed here is confounded by the fact that a single crop represents an average over irrigated and non-irrigated plots. Since yields of a particular crop from an irrigated plot is higher than yields of the same crop from a non-irrigated plot-- averaging over all the plots allocated to that crop without taking into consideration the positive yield effects from irrigation is a weakness of the method for the *returns* and *riskiness* classification of the crops discussed in this section.

Summary Findings. Appendix 9 presents the village-wise allocation of cultivable land between the "Low" and the "High" crop groups during the *kharif* seasons during 1975-84. The study village Shirapur in general had a higher proportion of land allocated to "Low" crop groups (in Shirapur, 83 percent of all land allocation over 10 years was to the "Low" group) compared to the other two villages; the total area planted in Shirapur in the *kharif* season also varied sharply from year to year. The study village Kanzara allocated the highest proportion of its cultivable land to the "High" crop group relative to the other two villages (in Kanzara, 80 percent of all land allocation over 10 years was to the "High" group), on the other hand Aurepalle gradually increased (with fluctuations) its allocation to the "High" crop group over time from 15 percent in 1975 to 63 percent in 1984.

IV.E.6. Planting and Harvest Periods

Source. The source of planting and harvest period demarcation information is the schedule "Y".

Methods. Sample households in the study villages operated at different dates in their different plots in a particular season, therefore the approach that has been followed to determine the demarcation of the *kharif* season into two periods, planting and harvesting, was based on taking village level averages (from households with plot-level averages).

The first step is to focus on crop operations in a particular plot for crops classified as *kharif* season crops. The crop operations include planting period work such as field preparation, minor repairs/fencing, manuring, uses of fertilizers, sowing, transplanting or planting, weeding and thinning, interculturing, plant protection such as uses of pesticides or insecticides, irrigating crops, harvest period work such as harvesting (including transport from field to threshing floor) main product and/or byproduct, harvest processing and works that can be done in either of the periods such as nursery raising, vegetable gardening, orchard cultivation, watching, supervision/management etc. For each plot with a *kharif* season crop I record a date for starting of planting period operations, a date for starting of harvest period operations and a date for end of harvest period operations.

The second step is to take average dates of the start of planting, start of harvesting and end of harvesting from plots operated by cultivator household in the sample by taking averages over the dates from all the plots.

The third and final step is to take average dates of start of planting, start of harvesting and end of harvesting for a particular village in a given year by taking averages over the average dates obtained for each of the cultivator households in the village in the particular year in question.

Summary Findings. The three abovementioned steps provide us with a list of start of planting, start of harvest and end of harvest of *kharif* seasons for each of the villages for every year under study. These dates differed within villages and also within years. A typical start of the planting period (including field preparation) of a *kharif* season predated the start of the monsoon-- around the month of May; a typical start of the harvest period of that season was towards the end of the monsoon-the first twenty days of the month of October and a typical end of that harvest period (including all post-harvest operations) was two to three weeks before the end of the calendar year.

IV.E.7. Wage Rates

Source. The source of information on male and female wage rates is the plot cultivation data in schedule Y.

Methods. I follow methods followed by Walker and Ryan (pp. 127) to calculate male and female wage rates for the first periods in the study villages. For each *kharif* season I sum the total amount of crop operations within the time periods specified in Section IV.E.6; I also record the hours and wages of particular crop operations done by a particular sex. For each sex, I calculate the average village-level nominal wage taking a weighted average of wages for particular crop operations done by that sex. Weights correspond to the proportions of crop operations in the total amount of work done by that sex during the specified period. For calculating real wages, I divide nominal wages by the corresponding consumer price indices (Section IV.E.2).

Summary Findings. Appendix 10 presents the male and female nominal and real wages in the study villages for *kharif* season planting periods for the period 1979 to 1984. Female wage rates, both nominal and real, lag behind the corresponding male wage rates. Nominal hourly wage rates for males in Aurepalle and Shirapur and females in Aurepalle registered substantial increases during this time starting out with lower bases than those of Kanzara-- while increases in nominal wages in Kanzara was to a smaller degree compared to the corresponding figures for other two villages.

IV.E.8. Labor Employment

Source. The source of village-level labor employment information is the schedule "K".

Methods. The structure of the questionnaire in schedule K changed in 1979, while in the years 1975 to 1978 the respondents were asked how many hours they worked the previous day in different activities, from 1979 onwards they were asked how many hours they had worked since the previous interview (interviews were taken at three-to-four week intervals). Now the section of schedule K from 1979 to 1984 is usable; yet again data for village Kanzara for 1983 is missing.

Schedule K records classification of labor employment by characteristics, such as farm work, off-farm non-government work, off-farm government work and own farm work etc. Farm work includes all work done for another farmer, regardless of its nature; off-farm non-government work includes all work done for private nonfarmer employers, this also regardless of the nature of work and off-farm government work includes all work for any government schemes (Singh, Binswanger and Jodha 1985, pp. 57). The schedule also records "*involuntary unemployment*". The respondent was asked the question: "*on how many days since the last visit (interview) did you try to find a job but failed to find one at the usual rates during this season*?" The respondent was considered involuntarily unemployed if he/she wanted to find a job but failed to find that at any wage, even in the case the respondent on failing to find an off-farm job returned to his/her own farm to work some extra hours (abovementioned, pp. 59).

I record three village-level variables as different indicators of ongoing conditions in the village off-farm labor market in the *kharif* season planting period, these are the following.

(1) The Involuntary Off-farm Unemployment Rate. This is calculated as following:

Village-level off-farm unemployment rate=

[total involuntary unemployment days]/[total demand for off-farm employment days].

The total demand for off-farm employment days is calculated as:

[total demand for off-farm employment days]=

[total involuntary unemployment days] + [total (off-) farm work days] +

[total off-farm non-government work days] + [total off-farm government work]

--summed across all the sample households in that particular study village.

(2) The Share of Off-farm Work in Total Work. This is calculated as following:

Village-level share of off-farm work (in total work)=

[total off-farm work]/[total work]

The total off-farm work is calculated as:

[total off-farm work]= [total (off-) farm work days] +

[total off-farm non-government work days] + [total off-farm government work].

The total work is calculated as:

[total work]= [total own farm work days] + [total (off-) farm work days] +

[total off-farm non-government work days] + [total off-farm government work].

-- summed across all the sample households in that particular study village.

(3) The Share of Non-agricultural Work in Total Off-farm Work, calculated as:

Village-level share of non-agricultural work (in total off-farm work)=

[total off-farm work (non-agricultural sources)]/ [total off-farm work (all sources)].

The total off-farm work (from non-agricultural sources) is calculated as:

[total off-farm work (non-agricultural sources)]=

[total off-farm non-government work days] + [total off-farm government work].

The total off-farm work (from all sources) is calculated as:

[total off-farm work (all sources)]= [total (off-) farm work days] +

[total off-farm non-government work days] + [total off-farm government work].

-- summed across all the sample households in that particular study village.

Summary Findings. In the Appendix, Table 11 presents the three indicator variables mentioned above for both male and female for the planting periods during the *kharif* season. In all the study villages, the share of off-farm work in total work is higher for women than men, and the share of non-agricultural work in total off-farm work is also higher for men than that for women. Male and female off-farm unemployment rates and the share of non-agricultural work in total off-farm work is in general higher in Shirapur than in the other two villages. In the Appendix, Table 12, on the other hand, presents the three indicator variables for both male and female for the harvesting periods during the harvesting season.

IV.E.9. Prices

Source. The source of price information is the schedules “Price” and “Y.”

Methods. Price information is reported from the schedule “Price.” From schedule “Y,” another set of price information is also collected which is the output price file, reported by the cultivator household as the prices they faced for their produce in the market. The second price information from schedule “Y” provides the harvest period prices of the crops. Relative prices were calculated from these harvest period prices, between two crops representing different crop return groups, such as the “high” group and the “low” group. In a number of cases where information was missing for harvest period price of a crop in the “Y” schedule, information was gathered from the “Price” schedule; an average of the village-level prices recorded for that crop for the months of October and November was taken as a proxy. There were some cases when even the corresponding information in the “Price” schedule was not available, for example, harvest period prices of jowar/sorghum (HYV) for Aurepalle in 1979 and 1980 and paddy (local variety) for Shirapur in 1979 and 1982, I interpolated these prices from the series of prices of the same crops in the same villages during the period 1978-83.

Summary Findings. Appendix 15 presents coefficients of correlations of harvest period price series from the three study villages for a total of 11 crops for the period of 1978-83. The harvest period prices from the villages show statistically significant positive correlations among each other.

IV.E.10. Measurement of the Depth of the Village Off-farm Labor Market

The "depth" of the village off-farm labor market (denoted as d_k throughout Chapter III, $0 \leq d_k \leq 1$) can be measured in two different ways. This can be measured either in terms of the share of non-agricultural labor in total labor demanded in that market (denoted by s_k where $0 \leq s_k \leq 1$) or in terms of the unemployment rate in that market (denoted by u_k where $0 \leq u_k \leq 1$) (Lamb 2003a, pp. 363). The off-farm labor market can be considered "deeper" or in other words more "diversified", the higher the share of non-agricultural labor in total labor demanded in that market, since that will indicate the market has a higher number of alternative sources of labor demand instead of being fully dependent on agriculture as the only source of demand. Another interpretation of the depth of the labor market could be based on its unemployment rate-- the lower the unemployment rate in that market the "deeper" or, in other words, the more vibrant is the labor market.

This concludes the section on the background of the data set, production environment in the study villages and a discussion on the methods followed and summary findings for construction of variables used for estimation (Chapter V) as well as different measurements of the depth of the village off-farm labor market. In the following chapter I concentrate on the estimation methods, results and explanations.

CHAPTER V

ESTIMATION

V.A. Censoring in a Panel data

The estimation[4] of this study centers on the household shares of cultivable land allocated to the low mean-low variance crop group (as the terms "*k*" in the model section). From the ICRISAT-India data set, a total of 467 observations have been collected for this term from a total of 102 households from the three study villages-- Aurepalle, Shirapur and Kanzara -- ranging over the *kharif* seasons in a six-year period from 1979 to 1984. For each particular household in a given year, the share of cultivable land is recorded if it engages in crop cultivation during the *kharif* season of that year[5]. On average, a total of 4.58 *kharif*-years of observations have been recorded for each household, whereas the minimum is one and the maximum is six.

The observations of household share of cultivable land are *censored* by the very nature of the construction of the term. The term has been constructed in the following manner. For each household, for a particular *kharif* season in a particular year, the total amount of cultivated land has been recorded, as well as total amount of land allocated to the crops falling into the category of "high" crop group and "low" crop group (in some cases, the land is allocated to some crops which do not fall into either of these groups, this is termed the "undecided" group). For a household, the sum of shares of land allocated to the "high",

[4] Appendix 16 presents the summary statistics of the variables that are used in different regressions of Chapter V.

[5] Out of 467 observations from 102 households from a maximum of six years of information, 51 households (50.00%) were reported six times, 15 households (14.71%) were reported five times, 11 households (10.78%) were reported four times, 6 households (5.88%) were reported three times, 5 households (4.90%) were reported two times and 14 households (13.73%) were reported only one time.

“low” and “undecided” groups is unity. Each of these groups --“high”, “low” and “undecided”-- is therefore doubly *censored* at the points of zero and one. Censoring in this case occurs because the variables to be explained are partly continuous but they have positive probability masses at the two extreme points-- zero and one. One can imagine censoring in this situation is due to some *corner solution outcomes*-- the household solves an optimization problem of distribution of land among groups of crops with different return characteristics- and for some households the optimal solution is at 0 or 1. Table 5 illustrates this point.

Variables	N	Mean	Standard Deviation	Censoring		
				Observations At 0	Observations Between 0 and 1	Observations At 1
Total Land (in acres)						
Total Crop Area	467	9.168	12.044			
Total “High” Group Area	467 (100)	5.636	9.710	119 (25.48)		
Total “Low” Group Area	467 (100)	3.509	4.595	124 (26.56)		
Total “Undecided” Group Area	467 (100)	0.023	0.176	455 (97.4)		
Shares of Land (in proportion)						
Share of “High” Group	467 (100)	0.536	0.408	119 (25.48)	226 (48.39)	122 (26.12)
Share of “Low” Group	467 (100)	0.461	0.408	124 (26.55)	226 (48.39)	117 (25.05)
Share of “Undecided” Group	467 (100)	0.003	0.036	455 (97.43)	12 (2.57)	0 (0.00)

Note. percentage of total observations in parenthesis.
Table 5. Censoring Pattern of the Land Allocation Variables.

Besides the issue of data censoring, the panel nature of the data brings in some additional complications. While in the classical linear model framework the error term in each time period is assumed to be uncorrelated with the explanatory variables at the same time period, for a panel data this assumption can turn out to be a very strong one. The problem arises from the influence of an unobserved, time-constant variable in the observations-- this is the *unobserved effect* in the panel data literature. Because in this type of data set, we follow the same individual or firm for some periods of time, their observed decision making or performance in each period will be influenced by their *unobserved* or *latent* characteristics. For the case of an individual, the example of an *unobserved effect* can be cognitive ability, motivation or personal upbringing. These are time-constant characteristics pertinent to that individual. For the case of a firm, the example of (nearly) time-constant *unobserved effects* can be managerial characteristics or firm structure.

The basic unobserved effects model can be expressed, for a randomly drawn cross section observation *i*, as

$$y_{it} = x_{it}\beta + c_i + u_{it} \qquad t = 1,2,\ldots\ldots,T \qquad (5.1)$$

where x_{it} is 1×K and this can contain variables that change across *t* but not *i*, variables that change across *i* but not *t*, and variables that change across *i* and *t* (*t* denotes time). The term c_i is the *unobserved effect*. The u_{it} is the *idiosyncratic error* terms since they change across *t* as well as across *i* (Wooldridge 2002, pp. 251).

One relevant discussion regards the way one can treat the *unobserved effect* c_i. It is possible to treat c_i as a *fixed effect* or a *random effect*. In traditional panel data models, c_i is called a “random effect” when it is treated as a random variable and a “fixed effect” when it is treated as a parameter to be estimated. Wooldridge (2002, pp. 251-2) points out that this discussion of whether c_i is a random variable or a parameter to be estimated is not suitable for microeconometric panel data applications, since with a large number of random draws from the cross section, it is reasonable to treat the *unobserved effects* as random draws from the population, the same as y_{it} and x_{it}. In a modern approach to this discussion, according to Wooldridge, the key issue involving c_i is whether or not it is uncorrelated with the observed explanatory variables x_{it}, t=1,2,…..,T.

In a more recent approach to the discussion of treatment of c_i, the term "random effect" implies zero correlation between the observed explanatory variables and the unobserved effect: $\mathrm{Cov}(x_{it}, c_i) = 0$, $t = 1,2,\ldots\ldots,T$ (a stronger version of the condition is a conditional mean independence assumption $E(c_i \mid x_{i1}, x_{i2}, \ldots\ldots, x_{iT}) = E(c_i)$ which is needed to fully justify statistical inference). On the other hand, in microeconometric applications, the term "fixed effect" does not usually mean that c_i is being treated as nonrandom. It means that one is allowing for arbitrary correlation between the *unobserved effect* c_i and the observed explanatory variables x_{it}. The question whether the random effects or the fixed effects are appropriate depiction of the *unobserved effect* in a particular panel data setting is to be solved empirically (aforementioned, pp. 252).

V.B. The Unobserved Effects Tobit Model Under Strict Exogeneity

Given the panel nature of the data set and censoring in it, an unobserved effects Tobit model under strict exogeneity is suited to describing the estimation of household land allocation shares. The estimation will concentrate on the linear approximations to the underlying household land allocation share equations as in equation (3.11). The econometric specification can be written as a notional demand for land allocation share of the form:

$K_{it}^* = x_{it}\beta + c_i + u_{it}$, $t = 1,2,\ldots..,T$ (5.2)

$K_{it} = 0$ if $K_{it}^* \leq 0$

$K_{it} = K_{it}^*$ if $0 \leq K_{it}^* \leq 1$

$K_{it} = 1$ if $K_{it}^* \geq 1$

$u_{it} \mid x_i, c_i \sim \text{Normal}(0, \sigma_u^2)$.

In equation (5.2) the term i refers to household while t refers to *kharif* crop-year. Here x_{it} is a vector of regressors and β is the coefficient to be estimated. While the *latent* land allocation share K_{it}^* may take values below 0 and above 1, one only observes a land allocation share K_{it} that takes values within the range of 0 and 1; K_{it} is 0 for values of K_{it}^* at zero and below and it is 1 for values of K_{it}^* at 1 and above. Therefore this is a case of doubly censored Tobit estimation. The term c_i is the *unobserved effect* and x_i contains x_{it} for all t. It is assumed that the idiosyncratic errors u_{it}, given the vector of regressors x_i and *unobserved effect* c_i are normally distributed. This assumption also implies that the x_{it} are *strictly exogenous* conditional on c_i. With an *unobserved effect*, this strict exogeneity assumption takes the form of:

$E(y_{it} \mid x_{i1}, x_{i2}, \ldots\ldots\ldots.., x_{iT}, c_i) = E(y_{it} \mid x_{it}, c_i) = x_{it}\beta + c_i$ for $t = 1,2,\ldots.,T$.

this assumption means that, once x_{it} and c_i are controlled for, x_{is} has no partial effect on y_{it} for $s \neq t$. In household crop cultivation context this assumption implies that once the current inputs have been controlled for along with the *unobserved effects* c_i, inputs used in other years would have no effect on output during the current year (Wooldridge 2002, pp. 252-3).

V.C. The Random Effects Tobit Model: Crop Choices[6]

In this section I report the random effects Tobit model regression results where the dependent variable is the household land allocation share to the low-mean and low-variance crop group.

In Table 6 results from different simple random effects Tobit estimations have been reported. The dependent variable is the household land allocation share to the low-mean and low-variance crop group while different combinations of independent variables have been tested. The objective of this exercise is to infer the pattern of relationships that household land allocation shares have with the key variables of interests in this study in a random effects Tobit framework. For example, in Table 6 the first set of estimations are of the simplest form-- they are single-regressor estimations. In Table 6, in Regression 1, I regress household land share to the low-mean and low-variance crop group on the planting period village-level male labor unemployment rate. Since the planting period village-level male labor unemployment is taken as a *proxy* for the household expectation of the unemployment rate in the village labor market at the harvest period, I expect this variable to have a positive effect on household land allocation share to the “low” crop group-- the higher the village-level unemployment rate in the village off-farm labor market, the higher the share of household land is expected to be allocated to the “low” crop group, *given other things held constant*. Table 6, Regression 1 reports this to be the case. The Regression 2 in Table 6 regress household land shares on the planting period female unemployment rate in the village off-farm labor market and the signs are found to be expected. Following the discussions in the model section, I expect a higher male or female planting period off-farm labor market wage rate and a higher share of irrigated land to lead to a lower share of household land

[6] Random Effects Tobit estimation is computed in STATA Version 8.

allocated to the "low" crop group, *given other things held constant*. In Table 6, the Regressions 4, 5 and 8 report the single-regressor random effects Tobit estimation results and the estimated coefficients are of expected signs. Another set of regressors do not provide expected results and the overall model significance is small in general-- that is the share of non-agricultural labor in total labor demand in the off-farm labor market for male and female[7]. One possible reason that non-agricultural labor share may not accurately reflect the risk-averse behavior of households in this context is that some government work programs are specifically targeted for villages with riskier production environment-- therefore household risk-averse decision-making can coincide with a higher share of non-agricultural labor in the off-farm labor market.

In the estimations reported throughout this chapter, I have used the planting period unemployment rate in the village off-farm labor markets as a *proxy* for the harvest period unemployment rate in those markets (for both male and female). The reasoning is as follows. At the start of the planting period households form their expectations regarding the harvesting period unemployment rates in the off-farm labor markets by observing some particular features of those markets currently available to them. One particular feature of the market known to households at the starting of the planting period, and therefore a plausible candidate for being a *proxy variable*, is the current unemployment rates in the market. If it is found that the planting period unemployment rate is a good *predictor* of the harvesting period unemployment rate, households may successfully use this planting period unemployment rate as a *proxy* for the yet unknown harvest period unemployment rate. Appendix 13 and 14 present scatter plots of the harvesting period unemployment rate against the planting period unemployment rate for male and female, respectively. Male harvesting period unemployment

[7] Appendix 17 reports the random effects Tobit estimation results with these regressors.

rate is found to be statistically significantly and positively correlated with male planting period unemployment rate (Pearson correlation of coefficient is 0.66525 and the p-value for the null of no linear correlation is 0.0036). Similarly female harvesting period unemployment rate is found to be statistically significantly and positively correlated with female planting period unemployment rate in the market (Pearson correlation of coefficient is 0.76576 and the p-value for the null of no linear correlation is 0.0003). This implies that male and female planting period unemployment rates can be considered to be *good predictors* for male and female harvesting period unemployment rates, respectively, in the village labor market.

In Table 6, regressions 3, 6, 7 and 9 combine different regressors and depict the way the pattern of estimation changes as more and more variables are controlled for compared to the simple single-regressor cases of 1, 2, 4, 5 and 8. When two unemployment terms (such as male and female) are combined together in a regression (regression no. 3 in Tables 6) the male unemployment rate still shows the expected sign but the female unemployment rate changes its sign compared to the single-regressor case. One possible explanation of this is the high correlation coefficients between the two unemployment rates (the coefficient of correlation is 0.9195, N=438). Similarly, when combined together in a single regression as in Regression 6, male planting period real wage rate changes the sign while female planting period real wage rate do not change the sign.

Table 7 reports the random effects Tobit estimation result (dependent variable is household land allocation to low-mean and low-variance crop group) with a number of regressors including the planting period labor market wage and unemployment rates for both sexes, the household share of irrigated land, rainfall uncertainty, the valuation of household non-financial assets, household characteristics and previous-year harvest period crop price ratios (price ratios are in the pattern of price of one crop from the "high" crop group in the numerator and price of one crop from the "low" crop group in the denominator). Household share of irrigated land and rainfall uncertainty terms are also found to be statistically significant. The coefficients for both male and female planting period labor market unemployment rates are statistically significant but of opposite signs in this full specification-- this remains difficult to explain. One plausible explanation could be that male and female planting period unemployment rates carry different information for the household forming an expectation of the harvest period unemployment rates and also contribute differently to household crop choice decisions. From the discussion in Section IV.D one notices that male and female laborers used to engage in mostly different tasks. One can argue that (a) since male wage rates are much higher compared to those of females for both planting and harvesting periods, (b) planting period unemployment rates and harvesting period unemployment rates are found to be positively correlated and (c) male share of off-farm work increases in the harvest period on average[8], the household can expect to incur more losses more from a prospective harvest period male unemployment compared to a prospective harvest period female unemployment. In that case a higher planting period male unemployment rate would lead households to turn to a risk-management strategy in the form of conservative crop choice decisions. Expected signs of male and female planting period wage rates lend support for the risk-management strategy as argued in the theoretical model, but the coefficients from these variables are not significant. The unexpected but statistically significant sign for female planting period unemployment rate still remains difficult to explain.

[8] Over 6 years period and 17 kharif season observations from 3 villages, average male share of total off-farm work in the planting period is 0.4376 and that of female is 0.5624 and average male share of total off-farm work in the harvesting period is 0.4734 and that of female is 0.5260.

A higher village-level standard deviation for monsoon onset date, standard deviation for total amount of monsoon rainfall and yearly deviation of total monsoon rainfall adds to riskiness of the agricultural production environment of the village-- households are expected to respond to these by allocating a higher share of land to the “low” crop group. Table 7 reports that the signs of standard deviation of monsoon onset date and total amount of monsoon rainfall as positive which is expected-- on the other hand the sign for yearly deviation of total monsoon rainfall is found to be negative-- which is not expected. Household asset valuations as well as household characteristics show mostly insignificant signs. Since crop price ratio terms are constructed as price of a crop form “high” group in the numerator and that of a crop from “low” group in the denominator-- I expect these ratios to have negative signs in regressions of household land share to “low” crop group-- a high price ratio in favor of the “high” crop group in the previous harvest is expected to motivate households away from the “low” group in favor of the “high” one. The estimation reported in Table 7 shows that this is the case in general-- though the ratios are mostly insignificant in signs-- one explanation is that these ratios are inadequate in capturing the overall price movements along the crop groups. Joint hypothesis test results indicate joint significance of labor market unemployment rates, labor market unemployment rates and wage rates combined and rainfall uncertainty terms. In Table 7 marginal effects and elasticities have also been reported for the variables at their respective mean values.

Random Effects Tobit Estimation *Dependent Variable: Land Share to "Low" Crop Group*					
Regression No.	Independent Variable(s)	Coefficient	Standard Errors	Z	Pr> |z|
1	Male Labor Unemployment	1.016***	0.332	3.06	0.002
Regression No. 1 N= 438 Number of Households= 101 Log Likelihood= -378.701 Wald chi-sq= 9.38 Pr>chi-sq= 0.0022					
2	Female Labor Unemployment	0.369	0.256	1.44	0.149
Regression No. 2 N=438 Number of Households=101 Log Likelihood= -382.249 Wald chi-sq= 2.08 Pr> chi-sq= 0.1494					
3	Male Labor Unemployment Female Labor Unemployment	3.304*** - 1.904***	0.789 0.599	4.19 -3.18	0.000 0.001
Regression No. 3 N=438 Number of Households= 101 Log Likelihood= -373.612 Wald chi-sq= 19.76 Pr> chi-sq= 0.0001					
4	Male Real Wage Rate	-0.6091***	0.154	-3.95	0.000
Regression No. 4 N=467 Number of Households=102 Log Likelihood= -395.648 Wald chi-sq= 15.61 Pr>chi-sq= 0.0001					
5	Female Real Wage Rate	-1.478***	0.215	-6.89	0.000
Regression No. 5 N=467 Number of Households= 102 Log Likelihood= -382.007 Wald chi-sq= 47.47 Pr> chi-sq= 0.0000					
6	Male Real Wage Rate Female Real Wage Rate	0.319 -1.827***	0.199 0.304	1.60 -6.01	0.109 0.000
Regression No. 6 N=467 Number of Households= 102 Log Likelihood= -380.73 Wald chi-sq= 51.41 Pr>chi-sq= 0.0000					
7	Male Labor Unemployment Female Labor Unemployment Male Real Wage Rate Female Real Wage Rate	2.775*** -1.745*** 0.576*** -1.828***	0.812 0.553 0.218 0.298	3.42 -3.16 2.64 -6.12	0.001 0.002 0.008 0.000
Regression No. 7 N=438 Number of Households= 101 Log Likelihood= -356.357 Wald chi-sq= 62.49 Pr>chi-sq= 0.0000					
8	Share of Irrigated Land	-1.288***	0.161	-8.02	0.000
Regression No. 8 N=467 Number of Households= 102 Log Likelihood= -373.045 Wald chi-sq= 64.30 Pr> chi-sq= 0.0000					
9	Male Labor Unemployment Female Labor Unemployment Male Real Wage Rate Female Real Wage Rate Share of Irrigated Land	2.147*** -1.663*** 0.484** -1.814*** -1.117***	0.771 0.528 0.226 0.312 0.139	2.79 -3.15 2.15 -5.81 -7.99	0.005 0.002 0.032 0.000 0.000
Regression No. 9 N=438 Number of Households= 101 Log Likelihood= -325.3696 Wald chi-sq= 124.77 Pr> chi-sq= 0.0000					

Table 6. Random Effects Tobit Estimation: Household Land Share to "Low" Crop Group.

Random Effects Tobit Estimation[1] *Dependent Variable: Household Land Share to "Low" Crop Group*			
Independent Variable(s)	Coefficient (*Standard Errors*)	z	Pr> |z|
Labor Market Wage and Unemployment:			
Male Planting Period Labor Unemployment	3.653 (*0.973*)***	3.75	0.000
Female Planting Period Labor Unemployment	-2.739(*0.580*)***	-4.72	0.000
Male Planting Period Real Wage Rate	-0.248 (*0.459*)	-0.54	0.589
Female Planting Period Real Wage Rate	-0.604 (*0.576*)	-1.05	0.294
Irrigation:			
Share of Irrigated Land	-1.444 (*0.149*)***	-9.66	0.000
Rainfall Uncertainty:			
Standard Deviation: *Monsoon Onset Date*	0.089 (*0.026*)***	3.49	0.000
Standard Deviation: *Total Monsoon Rainfall*	0.017 (*0.004*)***	4.19	0.000
(Village) Yearly Deviation: *Total Monsoon Rainfall*	-0.0004 (*0.0002*)**	-2.39	0.017
Household Assets:			
Log of Value of Household Non-financial Assets[2]	-0.130 (*0.114*)	-1.14	0.253
Household Characteristics:			
Number of Household Males Within Age of 15-45	0.029 (*0.037*)	0.78	0.433
Number of Household Females Within Age of 15-45	-0.013 (*0.036*)	-0.35	0.727
Number of Remittance Members Per Household	0.053 (*0.039*)	1.35	0.178
Age of Household Head	0.036 (*0.021*)*	1.76	0.079
Age of Household Head Squared	-0.0003(*0.0001*)**	-1.99	0.047
Education Level of Household Head	0.068 (*0.043*)	1.56	0.1180
Caste Index: Behrman	-0.001 (*0.001*)	-0.90	0.368
Crop Price Ratios[3]:			
Groundnut-Jower/Sorghum (Local)	-0.311 (*0.159*)*	-1.96	0.050
Jower/Sorghum (HYV)-Jower/Sorghum (Local)	-0.485 (*0.353*)	-1.37	0.170
Paddy (Local)-Jower/Sorghum (Local)	0.252 (*0.299*)	0.84	0.399
Chillies-Jower/Sorghum (Local)	-0.003 (*0.068*)	-0.06	0.954
Joint Hypothesis Tests: chi-square test for joint significance of unemployment: chi-sq= 23.36 and pr>chi-sq= 0.000 chi-square test for joint significance of wages: chi-sq= 3.26 and pr>chi-sq= 0.196 chi-square test for joint significance of unemployment and wages: chi-sq= 46.78 and pr>chi-sq= 0.000 chi-square test for joint significance of rainfall uncertainty terms: chi-sq= 92.99 and pr>chi-sq= 0.000 chi-square test for joint significance of household characteristics: chi-sq= 10.76 and pr>chi-sq= 0.149 chi-square test for joint significance of price ratios: chi-sq= 6.94 and pr>chi-sq= 0.139			
N=428 Number of Households= 98 Log Likelihood= -259.939 Wald chi-sq = 242.44 Pr> chi-sq= 0.0000 Observations: Uncensored= 208 Left-censored= 106 Right-censored= 114			

Continued to the Next Page.

Table 7. Random Effects Tobit Estimation (Full): Household Land Share to "Low" Crop Group.

Marginal Effects and Elasticities after Regression[4]:
y = fitted values (predict)
= 0.50864745

Variable(s) **(*At Mean Values*)**	*Marginal Effects* *dy/dx*	*Elasticities* *d(lny)/d(lnx)*
Male Planting Period Labor Unemployment	3.653***	1.372***
(At 0.191)	*(0.973)*	*(0.378)*
Female Planting Period Labor Unemployment	-2.739***	-1.165***
(At 0.216)	*(0.580)*	*(0.259)*
Male Planting Period Real Wage Rate	-0.248	-0.384
(At 0.786)	*(0.459)*	*(0.711)*
Female Planting Period Real Wage Rate	-0.604	-0.583
(At 0.491)	*(0.576)*	*(0.557)*
Share of Irrigated Land	-1.444***	-0.309***
(At 0.109)	*(0.149)*	*(0.040)*
Standard Deviation: *Monsoon Onset Date*	0.089***	2.070***
(At 11.731)	*(0.026)*	*(0.615)*
Standard Deviation: *Total Monsoon Rainfall*	0.017***	5.773***
(At 175.898)	*(0.004)*	*(1.422)*
(Village) Yearly Deviation: *Total Monsoon Rainfall*	-0.0004**	-0.001**
(At 1.102)	*(0.0002)*	*(0.0004)*
Log of Value of Household Non-financial Assets	-0.130	-1.016
(*At 3.961*)	*(0.114)*	*(0.892)*
Number of Household Males Within Age of 15 and 45	0.029	0.102
(At 1.759)	*(0.037)*	*(0.130)*
Number of Household Females Within Age of 15 and 45	-0.013	-0.047
(At 1.869)	*(0.036)*	*(0.134)*
Number of Remittance Members Per Household	0.053	0.039
(At 0.371)	*(0.039)*	*(0.029)*
Age of Household Head	0.036*	3.744*
(At 51.775)	*(0.021)*	*(2.145)*
Age of Household Head Squared	-0.0003**	-2.063**
(At 2827.48)	*(0.0001)*	*(1.045)*
Education Level of Household Head	0.068	0.262
(At 1.948)	*(0.043)*	*(0.169)*
Caste Index: Behrman	-0.001	-0.181
(At 54.474)	*(0.001)*	*(0.202)*
Groundnut-Jower/Sorghum (Local) Prices	-0.311*	-1.599*
(At 2.613)	*(0.159)*	*(0.828)*
Jower/Sorghum (HYV)-Jower/Sorghum (Local) Prices	-0.485	-0.844
(At 0.885)	*(0.353)*	*(0.618)*
Paddy (Local)-Jower/Sorghum (Local) Prices	0.252	0.545
(At 1.099)	*(0.299)*	*(0.648)*
Chillies-Jower/Sorghum (Local) Prices	-0.003	-0.023
(At 2.947)	*(0.068)*	*(0.394)*

Note: [1] ***significant at 10% level, **significant at 5% level and *significant at 1% level.
[2] at 1983 constant prices. [3] prices at the harvest period, one year earlier.
[4] standard errors of coefficients in parenthesis.

Table 7. Random Effects Tobit Estimation (Full): Household Land Share to “Low” Crop Group.

V.D. The Random Effects and The Fixed Effects Model: Household Crop Returns and Land Group Differences[9].

In this section I consider alternatives to a Tobit specification and am interested to observe pattern of the relationships in question from a slightly different perspective. The objective is to avoid full dependence on arbitrary crop groupings in the specification. Two alternative specifications to the Tobit are discussed in this section. One specification considers household crop returns as the relevant dependent variable-- this excludes any consideration of crop grouping and this also eliminates the censoring issue. The other one considers differences in household land allocation to "low" crop group and "high" crop group-- this, though still dependent on crop grouping, avoids the censoring issue.

The household crop income earnings from the current crop season reflect decision making by the household at the start of the planting season-- particularly the crop choice decision. In case the household decides to grow crops with lower means and lower variances of returns in stead of crops with higher means and higher variances of returns, this is expected to reflect on the year-end household crop returns. On the other hand, a household decision to grow riskier crops is expected to influence the year-end crop returns records as well. Since this data set follows the same households over a number of years it is possible to control for household *unobserved effects* and obtain some valuable information from the year-end crop returns data. In this section I concentrate on this aspect of the data. The argument is the following. The factors which lead households to choose a higher share of its land for less risky crops are expected to lead households to obtain lower year-end crop returns (household faces this lower return by choosing conservative risk-management strategies). In case this argument holds true, it is possible to regress household crop returns

[9] Cross-sections and time-series regressions are computed in STATA Version 8.

on the same set of regressors as was in the case of household land share allocation and obtain a similar pattern of relationships.

The second alternative approach is to consider the difference in household land allocation between the groups-- in this case the difference between the total amounts of land allocated to the "low" crop group and the "high" crop group. An estimation of this variable can explore the causes behind household land share differences between the two groups of crops.

In Table 8 regression coefficients have been reported from cross-sections time-series random effects and fixed effects estimations for comparison. Male planting period labor unemployment rate has the expected negative sign for both random effects and fixed effects estimation and for random effects is significant at 10% level. Higher male and female planting period real wage rates are expected to assure the household of a vibrant off-farm labor market with high wages at the harvest-- thereby reducing its incentive to allocate land to less riskier crops. This is expected to lead to a higher year-end household crop return. Similar to the cases of random effects Tobit estimation, the two real wages show different signs with the female one showing expected positive sign. Similar to the estimations in other sections, the share of irrigated land shows the expected (positive) and significant sign. In the fixed effects estimation, a number of rainfall uncertainty terms and household characteristics terms are dropped from the equation because of lack of variations within the group. Household valuation of assets shows the expected (positive) signs and is significant in case of the random effects estimation. In the case of random effects estimation the correlation between the *unobserved effect* and the regressors is assumed to be zero while in case of fixed effects estimation this correlation is allowed to take any arbitrary value (in this regression it is -0.907).

The Breusch-Pagan test is a Lagrange multiplier test which tests for random effects. The null hypothesis of this test is that the variance of the *unobserved effect* is zero-- which by default is a fixed effects specification. The random effects specification is appropriate in case the null hypothesis is rejected; this is the case in this regression with a chi-square test statistic of 284.60 (p-value=0.00). Therefore the Breusch-Pagan test in this regression suggests the use of a random effects specification (Table 8).

A Hausman test contrasts the appropriateness of random effects versus fixed effects estimation. The test in this regression is ordered in a way that a fixed effects specification is considered to be *consistent* under both null and alternative hypotheses while a random effects estimation is considered to be *inconsistent* under the alternative but efficient under the null. The Hausman test statistic is based on the difference in coefficients from the two regressions -- the null hypothesis is that this difference in coefficients is not systematic. The chi-square value for the Hausman test in this regression is 23.30 with a p-value of 0.025. This implies that a fixed effects estimation would be appropriate one with a significance level of 0.025 and higher (Table 8).

In Table 9 random and fixed effects estimation results have been reported for the regression with household land share differences (total household land to the “low” crop group minus total household land to the “high” crop group) as the dependent variable and the same set of regressors as in Table 8 except for one regressor-- in this estimation the constant price value of household operated plots is used to replace constant price valuation of household non-financial assets. In this regression the plot value term can be considered a *proxy* for land quality because a higher quality land is valued at a higher price than a lower quality land. One can expect households with lower quality land (lower plot value) would allocate higher proportion of its land to less risky crops. Therefore, a negative sign is expected for the plot value term in this land share difference ("low" minus "high") equation. This is the case in the regression result and for random effects estimation this term is highly significant.

In Table 9 the Breusch-Pagan Lagrange multiplier test for random effects has a chi-square test statistic of 97.25 (p-value=0.0). This supports the use of random effects specification. And the Hausman test on these two regressions has a chi-square test statistic of 16.54 (p-value= 0.168). This also supports the use of random effects specification for the present discussion.

Village-year dummies are utilized for regression but not reported here. One problem with using village-year dummies is that some key variables of interest, such as male and female planting period unemployment rate, are dropped from the regression because of collinearity problem. One possible explanation is that identification of a particular village-year is closely associated with the village-level terms such as village off-farm labor market unemployment rates at that particular year-- therefore this causes problems in estimation.

Random Effects & Fixed Effects Estimation *Dependent Variable: Household Income Earnings from Crop Cultivation*		
Independent Variable(s)	Coefficients (*Standard Errors*)	
	Random Effects	**Fixed Effects**
Labor Market Wage and Unemployment:		
Male Planting Period Labor Unemployment	-7796.266*	-4352.346
	(*4584.676*)	(*4753.026*)
Female Planting Period Labor Unemployment	2639.272	1601.977
	(*2713.462*)	(*2687.23*)
Male Planting Period Real Wage Rate	-3388.81	-13562.88***
	(*2133.745*)	(*3846.839*)
Female Planting Period Real Wage Rate	6813.805**	12364.98***
Irrigation:	(*2672.499*)	(*3361.408*)
Share of Irrigated Land	1292.358**	1550.765**
Rainfall Uncertainty:	(*651.307*)	(*679.38*)
Standard Deviation: *Monsoon Onset Date*	-426.37***	-
	(*139.86*)	
Standard Deviation: *Total Monsoon Rainfall*	-31.501	-
	(*22.066*)	
(Village) Yearly Deviation: *Total Monsoon Rainfall*	-0.638	-4.365***
	(*0.996*)	(*1.558*)
Household Assets:		
Log of Value of Household Non-financial Assets	2457.309***	518.946
Household Characteristics:	(669.25)	(*839.232*)
Number of Household Males Within Age 15- 45	-224.36	-
	(*302.52*)	
Number of Household Females Within Age 15-45	-42.27	879.354
	(*265.41*)	(*550.965*)
Number of Remittance Members Per Household	1196.356***	-
	(*333.20*)	
Age of Household Head	390.21**	563.106
	(*153.225*)	(*355.253*)
Age of Household Head Squared	-3.103**	1.887
	(*1.392*)	(*2.714*)
Education Level of Household Head	757.308**	-
	(*302.11*)	
Caste Index: Behrman	12.298	-
Crop Price Ratios:	(*13.955*)	
Groundnut-Jower/Sorghum (Local)	652.558	-2906.738**
	(*738.374*)	(*1426.124*)
Jower/Sorghum (HYV)-Jower/Sorghum (Local)	-962.915	-1580.794
	(*1690.264*)	(*1666.493*)
Paddy (Local)-Jower/Sorghum (Local)	610.560	2652.514*
	(*1445.396*)	(*1512.844*)
Chillies-Jower/Sorghum (Local)	310.052	318.016
	(*333.385*)	(*348.159*)

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Table 8. Random and Fixed Effects Estimations: Household Income Earnings from Crop Cultivation.

	Random Effects	Fixed Effects
R-Squares		
Within	0.147	0.188
Between	0.583	0.002
Overall	0.553	0.004
Correlation (u_i, Xb) Unobserved Effect and Regressors	0 (Assumed)	-0.907
Model Significance	Wald chi-sq= 183.89 Pr>chi-sq= 0.000	F-statistic= 5.23 Pr>F= 0.000
Rho Fraction of Variance Due to Unobserved Effects	0.659	0.969
F test Null Hypothesis: All Unobserved Effects= 0		F(97,316)=8.76 Pr>F=0.000
Breusch-Pagan Test Lagrange Multiplier Test for Random Effects Null Hypothesis: Var(u)= 0	chi-sq= 284.60 Pr>chi-sq= 0.0000	
Hausman Test Null Hypothesis: Difference in Coefficients Not Systematic	chi-sq= 23.30 Pr>chi-sq= 0.025	

Table 8. Random and Fixed Effects Estimation: Household Income Earnings from Crop Cultivation.

Random Effects & Fixed Effects Estimation *Dependent Variable: Household Land Allocation Difference Between "Low" Crop Group and "High" Crop Group*		
Independent Variable(s)	Coefficients (*Standard Errors*)	
	Random Effects	**Fixed Effects**
Labor Market Wage and Unemployment:		
Male Planting Period Labor Unemployment	58.115***	59.125***
	(*10.390*)	(10.989)
Female Planting Period Labor Unemployment	-33.588***	-32.786***
	(*6.127*)	(*6.153*)
Male Planting Period Real Wage Rate	2.425	-4.006
	(*4.657*)	(*8.616*)
Female Planting Period Real Wage Rate	-1.095	1.526
Irrigation:	(*5.896*)	(*7.617*)
Share of Irrigated Land	-6.891***	-7.287***
Rainfall Uncertainty:	(*1.307*)	(1.529)
Standard Deviation: *Monsoon Onset Date*	0.15	-
	(*0.261*)	
Standard Deviation: *Total Monsoon Rainfall*	0.192	-
	(*0.040*)	
(Village) Yearly Deviation: *Total Monsoon Rainfall*	-0.006*** (*0.002*)	-0.008** (*0.004*)
Land Value:		
Sum of Value of Household-Operated Plots	-0.007***	-0.003
Household Characteristics:	(*0.001*)	(*0.002*)
Number of Household Males Within Age 15- 45	-0.092	-
	(*0.383*)	
Number of Household Females Within Age 15-45	0.632*	1.917
	(*0.354*)	(*1.257*)
Number of Remittance Members Per Household	-2.114***	-
	(*0.443*)	
Age of Household Head	-0.508**	0.77
	(*0.219*)	(*0.803*)
Age of Household Head Squared	0.004**	-0.004
	(*0.002*)	(*0.006*)
Education Level of Household Head	-0.623	-
	(*0.419*)	
Caste Index: Behrman	0.027	-
Crop Price Ratios:	(*0.018*)	
Groundnut-Jower/Sorghum (Local)	-2.479	-5.149
	(*1.591*)	(*3.217*)
Jower/Sorghum (HYV)-Jower/Sorghum (Local)	-2.596	-3.616
	(*3.775*)	(*3.717*)
Paddy (Local)-Jower/Sorghum (Local)	-0.422	0.993
	(*3.196*)	(*3.325*)
Chillies-Jower/Sorghum (Local)	1.61*	1.67*
	(*0.731*)	(*0.763*)

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Table 9. Random and Fixed Effects Estimations: Household Land Allocation Difference Between "Low" Crop Group and "High" Crop Group.

	Random Effects	Fixed Effects
R-Squares Within Between Overall	 0.277 0.754 0.642	 0.303 0.112 0.158
Correlation (u_i, Xb) Unobserved Effect and Regressors	 0 (Assumed)	 -0.326
Model Significance	Wald chi-sq= 431.19 Pr>chi-sq= 0.000	F-statistic= 9.90 Pr>chi-sq= 0.000
Rho Fraction of Variance Due to Unobserved Effects	 0.230	 0.753
F test Null Hypothesis: All Unobserved Effects= 0		F (97,319)= 9.90 Pr>F=0.000
Breusch-Pagan Test Lagrange Multiplier Test for Random Effects Null Hypothesis: Var(u)= 0	 chi-sq= 97.25 Pr>chi-sq= 0.000	
Hausman Test Null Hypothesis: Difference in Coefficients Not Systematic	chi-sq= 16.54 Pr>chi-sq= 0.168	

Table 9. Random and Fixed Effects Estimations: Household Land Allocation Difference Between “Low” Crop Group and “High” Crop Group.

V.E. The Fixed Effects Tobit Model: Crop Choices[10].

For fixed effects Tobit regressions, particularly with a panel data where T is short but N is large such as the ICRISAT-India data, a suitable estimator is one provided by Honore (1992). Here I have used Honore estimator to estimate a fixed effects Tobit model.

Table 10 presents fixed effects Tobit estimates following Honore and for comparison I include the corresponding coefficients from the random effects Tobit model as well. Similar to Section V.C here I develop a simple fixed effects Tobit estimation beginning with single-regressor estimations and gradually controlling for more variables. One point to note is that standard errors from fixed effects Tobit estimations are generally of smaller magnitude compared to their counters in the random effects Tobit estimations. In most of the cases the coefficients are also of the smaller magnitude that those from random effects Tobit. The signs of the coefficients from both of the estimations are of the same.

Full specification estimation from the fixed effects Tobit regression is presented in Table 11. For comparison a counterpart random effects Tobit regression is also presented. Joint hypothesis test results are presented in Table and this shows similarity in chi-square test results from the fixed and the random effects estimations.

The variables used in regressions of this section follow similar pattern of signs as in the earlier sections. Male and female planting period unemployment rates and share of household irrigated land are the variables with significant signs from both sets of regressions. Urea fertilizer prices in 1983 constant prices have been placed in estimation in this set of estimation- the coefficient is found to be insignificant and of unexpected sign, which is difficult to explain.

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[10] Fixed Effects Tobit estimation is computed in GAUSS implementing Honore estimator.

Fixed Effects Tobit Estimation *Dependent Variable: Land Share to "Low" Crop Group*				
Independent Variable(s)	Coefficient (*Standard Errors*)	t-values	Random Effects Coefficients (*Standard Errors*)	z-values
Male Labor Unemployment	0.842 (*0.276*)	3.052	0.677 (*0.216*)	3.14
Regression No. 1 Function Value= 135.027 Chi-sq test for significance: chi-sq= 9.3 (p-value=0.002)				
Female Labor Unemployment	0.293 (*0.195*)	1.50	0.270 (*0.166*)	1.63
Regression No. 2 Function Value= 141.226 Chi-sq test for significance: chi-sq= 2.2 (p-value=0.133)				
Male Labor Unemployment	2.676 (*0.447*)	5.977	3.304 (*0.789*)	4.19
Female Labor Unemployment	-1.616 (*0.355*)	-4.547	-1.904 (*0.599*)	-3.18
Regression No. 3 Function Value= 126.527 Chi-sq test for joint significance: chi-sq= 36.5 (p-value= 0.000)				
Male Real Wage Rate	-0.507 (*0.114*)	-4.435	-0.609 (*0.154*)	-3.95
Regression No. 4 Function Value= 142.075 Chi-sq test for significance: chi-sq= 19.7 (p-value= 0.000)				
Female Real Wage Rate	-1.047 (*0.127*)	-8.273	-1.478 (*0.215*)	-6.89
Regression No. 5 Function Value= 130.448 Chi-sq test for significance: chi-sq= 68.5 (p-value= 0.000)				
Male Real Wage Rate	0.173 (*0.184*)	0.939	0.319 (*0.199*)	1.60
Female Real Wage Rate	-1.266 (*0.266*)	-4.751	-1.827 (*0.298*)	-6.01
Regression No. 6 Function Value= 129.884 Chi-sq test for joint significance: chi-sq= 69.2 (p-value= 0.000)				
Male Labor Unemployment	1.784 (*0.472*)	3.781	2.775 (*0.812*)	3.42
Female Labor Unemployment	-1.262 (*0.305*)	-2.621	-1.745 (*0.553*)	-3.16
Male Real Wage Rate	0.366 (*0.249*)	1.474	0.576 (*0.218*)	2.64
Female Real Wage Rate	-1.262 (*0.305*)	-4.133	-1.828 (*0.298*)	-6.12

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Table 10. Fixed Effects Tobit Estimation: Household Land Share to "Low" Crop Group.

Fixed Effects Tobit Estimation *Dependent Variable: Land Share to "Low" Crop Group*				
Regression No. 7 Function Value= 111.166 Chi-sq test for joint significance: chi-sq= 84.0 (p-value= 0.000)				
Share of Irrigated Land	-0.9 (*0.054*)	-16.79	-1.288 (*0.161*)	-8.02
Regression No. 8 Function Value= 126.131 Chi-sq test for significance: chi-sq= 281.7 (p-value= 0.000)				
Male Labor Unemployment	1.531 (*0.445*)	3.439	2.147 (*0.771*)	2.79
Female Labor Unemployment	-1.221 (*0.324*)	-3.771	-1.663 (*0.528*)	-3.15
Male Real Wage Rate	0.140 (*0.155*)	0.902	0.484 (*0.226*)	2.15
Female Real Wage Rate	-1.053 (*0.210*)	-5.006	-1.814 (*0.312*)	-5.81
Share of Irrigated Land	-0.896 (*0.053*)	-16.82	-1.117 (*0.139*)	-7.99
Regression No. 9 Function Value= 83.65 Chi-sq test for significance: chi-sq= 435.3 (p-value= 0.000)				

Table 10. Fixed Effects Tobit Estimation: Household Land Share to "Low" Crop Group.

Fixed Effects Tobit Estimation *Dependent Variable: Household Land Share to "Low" Crop Group*				
Independent Variable(s)	Fixed Effects Tobit Coefficient	Standard Error (FE)	Random Effects Tobit Coefficient	Standard Error (RE)
Labor Market Wage and Unemployment:				
Male Planting Period Labor Unemployment	2.588***	0.569	2.863***	0.853
Female Planting Period Labor Unemployment	-1.837***	0.387	-2.144***	0.564
Male Planting Period Real Wage Rate	0.422	0.374	-0.574	0.414
Female Planting Period Real Wage Rate	-0.870	0.540	-0.293	0.650
Irrigation:				
Share of Irrigated Land	-0.917***	0.072	-1.209***	0.122
Rainfall Uncertainty:				
(Village) Yearly Deviation: Monsoon Onset Date	0.003*	0.002	0.002	0.002
Household Assets:				
Log of Value of Household Non-financial Assets	0.050	0.109	0.089	0.104
Household Characteristics:				
Age of Household Head	0.030	0.049	0.097***	0.023
Age of Household Head Squared	-0.0006**	0.0003	-0.0007***	0.0001
Crop Price Ratios:				
Groundnut-Jower/Sorghum (Local)	0.018	0.145	-0.444	0.139
Jower/Sorghum (HYV)-Jower/Sorghum (Local)	0.068	0.272	0.452	0.264
Paddy (Local)-Jower/Sorghum (Local)	-0.235	0.216	-0.032	0.216
Fertilizer Prices:				
Urea Fertilizer, 1983 Constant Prices	-0.127	0.111	-0.212*	0.105

Joint Hypothesis Tests:
Chi-square test for joint significance:
(*Fixed Effects*) chi-sq= 387.2 p-value= 0.0%; Function Value= 78.879
Chi-square test for joint significance of unemployment rates:
(*Fixed Effects*) chi-sq= 23.0 p-value= 0.0%; *(Random Effects)* chi-sq= 14.52 p-value= 0.007%
Chi-square test for joint significance of wage rates:
(*Fixed Effects*) chi-sq= 2.7 p-value= 10.1%; *(Random Effects)* chi-sq= 16.01 p-value= 0.03%
Chi-square test for joint significance of unemployment and wage rates:
(*Fixed Effects*) chi-sq= 29.6 p-value= 0.0%; *(Random Effects)* chi-sq= 44.73 p-value= 0.00%
Chi-square test for significance of share of irrigated land:
(*Fixed Effects*) chi-sq= 324.0 p-value= 0.0%; *(Random Effects)* chi-sq= 97.49 p-value= 0.00%
Chi-square test for joint significance of household characteristics:
(*Fixed Effects*) chi-sq= 7.2 p-value= 0.7%; *(Random Effects)* chi-sq= 23.87 p-value= 0.00%
Chi-square test for joint significance of previous year price ratios:
(*Fixed Effects*) chi-sq= 2.5 p-value= 11.6%; *(Random Effects)* chi-sq= 17.03 p-value= 0.07%

Table 11. Fixed Effects Tobit Estimation (Full): Household Land Share to "Low" Crop Group.

CHAPTER VI

CONCLUSION

Risk and *behavioral responses to risk* remain a fascinating area for investigation in development economics. The study of household responsiveness to expectations of unfavorable shocks in production or labor income and *ex ante* decision making given limited available opportunities for *ex post* consumption smoothing has important policy implications in developing countries.

The primary objective of this dissertation has been to examine the link between agricultural production decisions and off-farm labor market opportunities available to cultivator households in a developing country context. The overall conclusion of this dissertation is that there is a strong relationship between agricultural production decisions and off-farm labor market opportunities available to households. A deeper understanding of this relationship is expected to help formulate effective agricultural policies directed at reducing rural poverty in the developing countries.

One particular feature of this dissertation is linking the developing country farmers' crop choice decisions with their off-farm labor market opportunities. Given a risky production environment the farmer evaluates the riskiness of his production activities taking into account all factors that contribute to this riskiness before deciding on crop choices. One of these factors that the farmer takes into account is the depth of the off-farm labor market at a future period of time. Since he can use labor supply in the off-farm labor market as *insurance* against crop income risk-- expectation of a low depth of that market leads the farmer into more conservative production decisions, i.e., allocation of more of his land to safer crops. This ‘labor market’ explanation of crop choice is perhaps the most interesting (and innovative) feature of this dissertation.

A two period stochastic dynamic programming model is developed to explain behavioral aspects of household decision-making under production and labor market depth uncertainty. The testable hypothesis of this paper is that *cultivator households’ expectations regarding the off-farm labor market at a later period influence its crop choice decisions.* It has been shown that under some particular conditions, particularly under expectation of a negative rainfall shock, risk-averse farmers’ expectations of a lower depth of the market or a lower wage rate in that market at the next period would lead them to allocate more of their land to safe crops as a particular form of *risk-management strategy*. In the extension to the basic model the farmers are also shown to make risky crop choice decisions in the presence of some risk-mitigating factors in their production environment, such as a higher share of irrigated land.

For estimation, a panel data set of households from three villages in the semi-arid tropics area of India from the ICRISAT survey has been used. Fixed effects and random effects Tobit specifications for estimating household land share allocation and fixed effects and random effects specifications for estimating household crop returns and land allocation differences have been used. The estimation results in general support the link between household crop choice decisions and labor market unemployment and wage terms as modeled in the theoretical model section. The regression results indicate a significant impact of household expectation of the harvesting period male unemployment rate on crop choices, taking planting period male unemployment rate as a proxy. The results also indicate the strong influence of irrigation on crop choices, also modeled in the model section. On the other hand, the results lend weak support for the linkage between crop choice decisions and the non-agricultural labor share in total labor demanded in the village labor market.

The panel data set used for estimation is a short one and it suffered from the problem of missing information and partly unusable information as well as attrition. A more accurate data set for investigating the issues raised in this paper remains an objective for future research. Concerns remain for the general applicability of the model since it is constructed primarily in the context of the semi-arid tropics of India-- the villages in the study are characterized by monsoon rainfall uncertainty and ready availability of the off-farm labor market opportunities. It still remains to be investigated whether the basic ideas behind this paper will still hold in other places where some other form of off-farm income source plays the role of *insurance* for crop income shocks-- such as remittance earnings or transfer payments.

My further research into this issue of crop choice will aim at relaxing a number of restrictions imposed on the model. Particularly, zero availability of credit and remittances or transfer payments. Another topic for my further research is the intrahousehold decision-making process involving crop choices, such as the roles of male and female members of the household in deciding which crops to plant.

One implication of this relationship between crop choice decisions and off-farm labor market opportunities as discussed in this dissertation is that it is possible to promote crops with higher returns in risky agricultural production areas if employment uncertainty in the off-farm labor market is reduced.

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APPENDIX

Appendix 1. Rainfall Shock Variables for the Study Villages.

Mean Values of the Variables					
Village	Monsoon Onset	Monsoon End	Total Monsoon Rain	Number of Rainy Days	Intraseasonal Droughts (Period 1)
Aurepalle 1976-86	177.73	292.45	491.79	41.73	17.27
Shirapur 1975-86	171.92	293.92	520.97	38.17	17.67
Kanzara 1975-86	170	273.83	691.19	45	15

Mean Values of the Variables					
Village	Intraseasonal Droughts (Period 2)	Length of Monsoon	Fraction of Rainy Days	Average Rain per Day	Average Rain per Rainy Day
Aurepalle 1976-86	12.18	114.73	0.36	4.49	13.13
Shirapur 1975-86	13.25	122	0.31	4.25	13.84
Kanzara 1975-86	8.83	103.83	0.44	6.78	16.24

Standard Deviation of the Variables					
Village	Monsoon Onset	Monsoon End	Total Monsoon Rain	Number of Rainy Days	Intraseasonal Droughts (Period 1)
Aurepalle 1976-86	22.82	16.81	161.61	13.86	4.52
Shirapur 1975-86	14.39	19.99	220.13	13.61	13.62
Kanzara 1975-86	7.07	11.13	144.34	13.56	9.18

Standard Deviation of the Variables					
Village	Intraseasonal Droughts (Period 2)	Length of Monsoon	Fraction of Rainy Days	Average Rain per Day	Average Rain per Rainy Day
Aurepalle 1976-86	4.71	27.47	0.07	1.59	6.00
Shirapur 1975-86	5.22	22.72	0.09	1.67	3.73
Kanzara 1975-86	3.24	11.17	0.13	1.83	4.48

Appendix 2. Consumer Price Index for the Study Villages.

Year	State/Village		
	Andhra	Maharashtra	Maharashtra
	Aurepalle	Shirapur	Kanzara
1975	0.667	0.487	0.487
1976	0.647	0.609	0.609
1977	0.681	0.629	0.629
1978	0.647	0.621	0.621
1979	0.709	0.711	0.711
1980	0.81	0.796	0.796
1981	0.938	0.902	0.902
1982	0.954	0.896	0.896
1983	1	1	1
1984	1.04	1.02	1.02

Source: CPIAL, Directorate of Economics and Statistics, India
(Walker and Ryan, 1990, pp. 67)
Note: Base Year 1983

Appendix 3. Sample Household Characteristics Information by Village in 1979.

Variable Name	All Mean (N=124)	Aurepalle Mean (N=41)	Shirapur Mean (N=43)	Kanzara Mean (N=40)
Household Size	5.68 (2.46)	5.73 (2.18)	5.74 (2.15)	5.55 (3.04)
Age of Household Head	48.44 (11.03)	52.34 (11.32)	48.02 (9.91)	44.88 (10.82)
Female Household Head (Female=1, Male=0)	0.18 (0.38)	0.27 (0.45)	0.09 (0.29)	0.18 (0.38)
Number of Household Males Within Age 15-45	1.27 (0.93)	1.27 (0.90)	1.30 (0.99)	1.25 (0.93)
Number of Household Females Within Age 15-45	1.42 (0.90)	1.27 (0.87)	1.58 (0.98)	1.40 (0.90)
Sum of Numbers of Household Males and Females Within Age 15-45	2.69 (1.58)	2.54 (1.40)	2.88 (1.64)	2.65 (1.70)
Households With At least One Male or Female Within Age 15-45 (Yes=1, No=0)	0.94 (0.25)	0.93 (0.26)	0.98 (0.15)	0.90 (0.30)
Average Age of Household Males Within Age 15-45	28.70 (7.98)	27.56 (7.79)	28.27 (8.29)	30.32 (7.84)
Average Age of Household Females Within Age 15-45	29.46 (7.25)	28.51 (8.12)	30.73 (6.60)	28.96 (7.05)
Education Level of Household Head (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.79 (1.25)	1.46 (0.87)	1.91 (1.36)	2.00 (1.41)
Education Level of Principal Female Member (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.35 (0.84)	1.08 (0.35)	1.28 (0.77)	1.70 (1.11)
Not Illiterate Household Head (Illiterate=0, Otherwise=1)	0.35 (0.48)	0.27 (0.45)	0.40 (0.49)	0.40 (0.50)
Number of Remittance Members Per Household	0.30 (0.95)	0.20 (0.46)	0.14 (0.41)	0.58 (1.53)
Household Receives Remittance (Yes=1, No=0)	0.15 (0.36)	0.17 (0.38)	0.12 (0.32)	0.18 (0.38)
Caste Ranking	5.28 (3.95)	7.71 (4.13)	2.81 (2.31)	5.40 (3.60)
Doherty Caste Ranking	3.37 (2.20)	4.29 (2.12)	2.79 (2.26)	3.05 (1.96)
Behrman Caste Ranking	49.81 (27.68)	48.81 (28.66)	50.61 (26.62)	50 (28.43)
J.G.Ryan Caste Ranking	2.38 (1.20)	2.88 (1.67)	1.88 (1.15)	2.40 (1.08)

Note: Standard Deviation of the Observation in Parenthesis.

Appendix 4. Sample Household Characteristics Information by Land Class in 1979.

Variable Name	All Mean (N=124)	Landless Labor (N=32)	Small Farmer (N=31)	Medium Farmer (N=30)	Large Farmer (N=31)
Household Size	5.68 (2.46)	4.66 (2.70)	5.52 (1.86)	6.07 (2.30)	6.52 (2.59)
Age of Household Head	48.44 (11.03)	50.84 (9.90)	47.35 (11.23)	47.17 (11.79)	48.26 (11.31)
Female Household Head (Female=1, Male=0)	0.18 (0.38)	0.22 (0.42)	0.16 (0.37)	0.13 (0.35)	0.19 (0.40)
Number of Household Males Within Age 15-45	1.27 (0.93)	1.03 (0.90)	1.23 (0.88)	1.53 (1.01)	1.32 (0.91)
Number of Household Females Within Age 15-45	1.42 (0.90)	1.09 (0.89)	1.45 (0.62)	1.50 (1.08)	1.65 (1.11)
Sum of Numbers of Household Males and Females Within Age 15-45	2.69 (1.58)	2.12 (1.66)	2.68 (1.33)	3.03 (1.54)	2.97 (1.66)
Households With At least One Male or Female Within Age 15-45 (Yes=1, No=0)	0.94 (0.25)	0.78 (0.42)	1.00 (0.00)	0.97 (0.18)	1.00 (0.00)
Average Age of Household Males Within Age 15-45	28.70 (7.98)	29.20 (6.95)	28.67 (9.17)	27.80 (7.33)	29.19 (8.50)
Average Age of Household Females Within Age 15-45	29.46 (7.25)	28.38 (8.28)	30.61 (7.29)	27.69 (5.50)	30.66 (7.57)
Education Level of Household Head (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.79 (1.25)	1.25 (0.72)	1.29 (0.74)	1.93 (1.08)	2.71 (1.66)
Education Level of Principal Female Member (Illiterate=1, Read and Write=2,..., Graduate=7, etc.)	1.35 (0.84)	1.03 (0.18)	1.03 (0.18)	1.5 (1.04)	1.84 (1.13)
Not Illiterate Household Head (Illiterate=0, Otherwise=1)	0.35 (0.48)	0.13 (0.34)	0.16 (0.37)	0.50 (0.51)	0.65 (0.49)
Number of Remittance Members Per Household	0.30 (0.95)	0.25 (0.92)	0.03 (0.18)	0.13 (0.35)	0.77 (1.54)
Household Receives Remittance (Yes=1, No=0)	0.15 (0.36)	0.13 (0.34)	0.03 (0.18)	0.13 (0.35)	0.32 (0.48)
Caste Ranking	5.28 (3.95)	7.19 (3.85)	6.55 (3.39)	4.93 (4.31)	2.45 (2.32)
Doherty Caste Ranking	3.37 (2.20)	4.65 (2.30)	4.23 (1.91)	2.90 (1.90)	1.71 (1.35)
Behrman Caste Ranking	49.81 (27.68)	34.17 (26.89)	36.77 (21.48)	55.79 (22.72)	72.70 (20.68)
J.G.Ryan Caste Ranking	2.38 (1.20)	3.06 (1.12)	2.90 (1.01)	2.13 (1.07)	1.42 (0.81)

Note: Standard Deviation of the Observation in Parenthesis.

Appendix 5. Sample Household Non-financial Asset Valuations by Land Class, 1979-1984, 1983 Constant Prices, in Rupees.

Value of Assets (1983 Constant Prices)	Landholding Class				
	All	Landless Labor	Small Farmer	Medium Farmer	Large Farmer
1979					
Value of Total Assets	10051.70 (12901.81)	2705.47 (2398.67)	6126.40 (3163.08)	8615.30 (6271.10)	22269.9 (19805.7)
Value of Farm Building	4791.38 (4869.99)	1897.27 (1746.07)	2920.99 (1195.54)	4421.08 (2532.36)	9443.83 (7035.15)
Value of Other Assets	5382.14 (9995.88)	1011.47 (1102.80)	3205.40 (2892.43)	4194.23 (4580.41)	12826.08 (17044.31)
1980					
Value of Total Assets	11034.35 (18819.89)	2686.34 (2288.49)	7036.75 (5105.77)	8659.10 (7272.27)	25011.04 (32138.56)
Value of Farm Building	5167.18 (5581.94)	2043.08 (1690.89)	3065.96 (2044.52)	4773.77 (4247.78)	10100.76 (7603.58)
Value of Other Assets	6039.41 (15633.28)	925.06 (1222.70)	3970.79 (4539.59)	3885.34 (3936.48)	14910.28 (28594.34)
1981					
Value of Total Assets	9887.61 (10886.32)	2832.52 (2193.85)	7069.15 (5566.26)	8004.51 (6008.89)	21550.30 (14407.46)
Value of Farm Building	5646.48 (6180.67)	2028.90 (1480.39)	3346.74 (2051.64)	4537.95 (3705.49)	12354.49 (8189.95)
Value of Other Assets	4336.03 (5754.84)	938.88 (1129.96)	3722.41 (4963.36)	3466.56 (3521.95)	9195.81 (7730.55)
1982					
Value of Total Assets	10224.21 (13366.2)	3075.07 (2490.04)	7047.12 (5428.79)	8601.42 (6447.18)	22173.23 (21026.74)
Value of Farm Building	5712.56 (5871.63)	2105.05 (1543.09)	3640.87 (2241.80)	5397.34 (4728.99)	11466.46 (7624.25)
Value of Other Assets	4645.57 (8827.48)	1110.34 (1377.39)	3523.71 (4231.23)	3204.07 (2850.76)	10706.78 (15343.4)
1983					
Value of Total Assets	10255.88 (13567.56)	3330.90 (2548.94)	6271.08 (4503.95)	8563.17 (6434.83)	22885.37 (21285.42)
Value of Farm Building	6337.265 (8431.31)	2188.52 (1402.09)	3536.67 (2238.11)	5335 (4492.39)	13874 (13170.24)
Value of Other Assets	4077.05 (6404.19)	1361.23 (1580.78)	2734.41 (3291.11)	3201.17 (3574.00)	9011.37 (10330.46)
1984					
Value of Total Assets	12320.67 (12365.6)	4896.13 (4623.37)	8545.68 (7198.06)	11973.04 (10505.95)	23844.66 (15221.34)
Value of Farm Building	7303.11 (7173.97)	3135.84 (2285.36)	5705.52 (4760.10)	6953.38 (5623.54)	13202.24 (9575.44)
Value of Other Assets	5141.34 (7121.05)	1864.82 (3115.59)	3030.35 (3705.35)	5019.66 (7572.14)	10642.42 (8985.03)

Note. Standard Deviation of the Observation in Parenthesis.

Appendix 6. Crop Returns in the Study Villages 1975-84, 1983 Constant Prices, *Kharif* Season Crops, Per Acre, in Rupees

Name of Crop	Weighted Average of Net Income	Weighted Average of Net Return	Weighted Average of Standard Deviation of Net Income	Weighted Average of Standard Deviation of Net Return
Groundnuts	422.82	520.92	448.59	469.58
Castor (HYV)	214.87	315.28	272.59	288.00
Bajra/Pearl Millet (HYV)	227.23	299.87	230.00	236.94
Jowar/Sorghum (HYV)	369.95	462.73	354.35	362.83
Maize (Local)	49.92	125.33	358.52	357.14
Paddy (Local)	530.59	673.50	536.61	465.78
Paddy (HYV)	866.45	1050.28	474.77	460.14
Wheat (HYV)	342.90	444.96	412.54	438.92
Cotton (Local)	271.22	361.55	243.90	258.30
Cotton (HYV)	1225.15	1369.31	899.29	921.20
Lemon	1990.30	2262.01	2165.13	2187.07
Sugarcane	587.77	744.81	2120.49	2128.27
Onion	371.68	582.90	876.36	834.26
Chillies	721.91	912.33	992.11	1079.26
Other Vegetables	1280.93	1746.37	3186.54	3554.59
Green Fodder Crops	140.30	251.76	445.90	477.27
Sesamum	39.57	75.75	43.32	52.06
Castor (Local)	72.53	129.28	147.90	164.03
Sunflower	72.23	138.02	216.38	189.36
Safflower	40.17	64.60	75.65	84.82
Bajra/Pearl Millet (Local)	48.15	64.65	46.73	92.67
Jowar/Soghum (Local)	122.37	191.95	188.79	197.84
Wheat (Local)	-15.81	107.23	199.12	209.67
OtherCereals	-25.73	-4.77	7.47	7.93
Other Fruits	-3051.20	-2612	3.97	9.61
Redgram (Tur)/Pigoenpea	110.11	146.19	185.83	202.61
Greengram (Mung)	110.58	190.75	227.05	232.42
Blackgram (Urad)	168.73	307.63	105.18	102.86
Bengalgram (Chenna)/ Chickpea	112.28	169.68	160.51	184.65
Other Pulses	-8.65	26.53	67.58	66.44
Other Spices (Salt,Tamarind etc.)	-28.75	1.67	182.29	103.68

Note. Not Included Because of Small Number of Observations: Maize (HYV), Tomato, Orange, Linseed, Other Oilseeds, Other Minor Millets, Grass and Other Dry Fodder, Brinjal, Other Fiber Crops.

Appendix 7. Rankings of Crops in terms of Return Measurements in the Study Villages 1975-84, Following Appendix 6

Name of Crop	(1) Ranking in terms of Weighted Average of Net Income	(2) Ranking in terms of Weighted Average of Net Return	(3) Ranking in terms of Weighted Average of Standard Deviation of Net Income	(4) Ranking in terms of Weighted Average of Standard Deviation of Net Return
Groundnuts	8	9	9	8
Castor (HYV)	14	13	14	14
Bajra/Pearl Millet (HYV)	13	15	16	16
Jowar/Sorghum (HYV)	10	10	13	12
Maize (Local)	23	23	12	13
Paddy (Local)	7	7	7	9
Paddy (HYV)	4	4	8	10
Wheat (HYV)	11	11	11	11
Cotton (Local)	12	12	15	15
Cotton (HYV)	3	3	5	5
Lemon	1	1	2	2
Sugarcane	6	6	3	3
Onion	9	8	6	6
Chillies	5	5	4	4
Other Vegetables	2	2	1	1
Green Fodder Crops	16	16	10	7
Sesamum	26	25	29	29
Castor (Local)	21	22	24	23
Sunflower	22	21	18	21
Safflower	25	27	26	27
Bajra/Pearl Millet (Local)	24	26	28	26
Jowar/Soghum (Local)	17	17	20	20
Wheat (Local)	28	24	19	18
OtherCereals	29	30	30	31
Other Fruits	31	31	31	30
Redgram (Tur)/Pigoenpea	20	20	21	19
Greengram (Mung)	19	18	17	17
Blackgram (Urad)	15	14	25	25
Bengalgram (Chenna)/Chickpea	18	19	23	22
Other Pulses	27	28	27	28
Other Spices (Salt,Tamarind etc.)	30	29	22	24

Appendix 8. Classification of Crops in terms of Return and Risk Characteristics 1975-84, Following Appendix 7

Name of Crop	Return and Risk Classification	Comment
Groundnuts	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Castor (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Bajra/Pearl Millet (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Jowar/Sorghum (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Maize (Local)	High	Split case, placed "High" in comparison with Blackgram (urad)
Paddy (Local)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Paddy (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Wheat (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Cotton (Local)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Cotton (HYV)	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Lemon	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Sugarcane	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Onion	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Chillies	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Other Vegetables	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Green Fodder Crops	High	(1),(2),(3) and (4) in Appendix 7 consistently above 15/16
Sesamum	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Castor (Local)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Sunflower	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Safflower	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16

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Appendix 8. (Continued from the Previous Page)

Name of Crop	Return and Risk Classification	Comment
Bajra/Pearl Millet (Local)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Jowar/Sorghum (Local)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Wheat (Local)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Other Cereals	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Other Fruits	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Redgram (Tur)/Pigeonpea	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Greengram (Mung)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Blackgram (Urad)	Low	Split case, placed "Low" in comparison with Maize (Local)
Bengalgram (Chenna)/ Chickpea	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Other Pulses	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16
Other Spices (Salt,Tamarind etc.)	Low	(1),(2),(3) and (4) in Appendix 7 consistently below 15/16

Appendix 9. Total Crop Areas Planted in the Study Villages By Crop Groups, *Kharif* Season, 1975-84, in Acres.

Year	Area Planted	Area Classified in Groups[a]	"High" Group Area	"Low" Group Area	Proportion of "High" Group	Proportion of "Low" Group
Aurepalle						
1975	286.09	286.09	41.53	244.56	0.15	0.85
1976	285.76	285.76	37.61	248.15	0.13	0.87
1977	230.66	230.41	44.45	185.96	0.19	0.81
1978	260.36	260.36	55.9	204.46	0.21	0.79
1979	204.34	204.34	50.75	153.59	0.25	0.75
1980	250.88	250.13	40.7	209.43	0.16	0.84
1981	245.59	245.59	116.17	129.42	0.47	0.53
1982	220.46	220.46	141.58	78.88	0.64	0.36
1983	219.51	219.51	152.93	66.58	0.70	0.30
1984	195.2	192.7	122.02	70.68	0.63	0.37
Shirapur						
1975	134.32	133.32	19.52	113.8	0.15	0.85
1976	165.45	165.45	59.55	105.9	0.36	0.64
1977	139.35	138.95	19.8	119.15	0.14	0.86
1978	197	195.9	26.4	169.5	0.13	0.87
1979	25.27	24.92	7.57	17.35	0.30	0.70
1980	92.6	91.1	21.1	70	0.23	0.77
1981	93.87	92.87	12.47	80.4	0.13	0.87
1982	87.65	87.65	8.5	79.15	0.10	0.90
1983	161.57	160.97	23.22	137.75	0.14	0.86
1984	107.14	105.64	10.55	95.09	0.10	0.90
Kanzara						
1975	418.5	418.5	325.1	93.4	0.78	0.22
1976	438.7	438.7	337.45	101.25	0.77	0.23
1977	435.1	435.1	336.2	98.9	0.77	0.23
1978	383.68	380.96	313.71	67.25	0.82	0.18
1979	409.08	409.08	293.11	115.97	0.72	0.28
1980	393.99	393.86	321.81	72.05	0.82	0.18
1981	372.24	371.49	292.57	78.92	0.79	0.21
1982	412.85	412.85	334.43	78.42	0.81	0.19
1983	387.05	387.05	324.3	62.75	0.84	0.16
1984	402.17	400.27	366.47	33.8	0.92	0.08

Note. [a] total area planted excluding areas plotted with crops not classified in the crop group list.

Appendix 10. Male and Female Wage Rates in the Study Villages, 1979-84, in Rupees/Hour, Planting Period, *Kharif* Season, Nominal Wage in Current Prices and Real Wage in 1983 Constant Prices

Village	Year	Nominal Wage		Real Wage	
		Male	Female	Male	Female
Aurepalle	1979	0.37	0.24	0.52	0.34
	1980	0.44	0.32	0.54	0.40
	1981	0.54	0.42	0.57	0.45
	1982	0.78	0.56	0.82	0.59
	1983	1.02	0.77	1.02	0.77
	1984	1.03	0.74	1.00	0.72
Shirapur	1979	0.55	0.28	0.78	0.39
	1980	0.52	0.30	0.65	0.37
	1981	0.53	0.41	0.59	0.46
	1982	0.77	0.39	0.86	0.44
	1983	1.01	0.47	1.01	0.47
	1984	1.20	0.43	1.18	0.42
Kanzara	1979	0.56	0.30	0.79	0.42
	1980	0.57	0.30	0.71	0.38
	1981	0.65	0.42	0.72	0.47
	1982	0.79	0.51	0.88	0.57
	1983	0.90	0.52	0.90	0.52
	1984	0.89	0.59	0.87	0.58

Appendix 11. Village-level Male and Female Off-farm Unemployment Rate,
Share of Off-farm Work in Total Work and
Share of Non-agricultural Work in Total Off-Farm Work in the Study Villages,
Kharif Season, Planting Period, 1979-84

Village	Year	Share of Off-Farm Work in Total Work		Off-farm Unemployment Rate		Share of Non-agricultural Work in Total Off-farm Work	
		Male	Female	Male	Female	Male	Female
Aurepalle	1979	0.30	0.84	0.19	0.20	0.28	0.01
	1980	0.30	0.87	0.24	0.19	0.35	0
	1981	0.38	0.90	0.18	0.20	0.33	0
	1982	0.43	0.88	0.12	0.18	0.23	0
	1983	0.42	0.89	0.08	0.14	0.19	0.03
	1984	0.22	0.92	0.19	0.16	0.59	0.01
Shirapur	1979	0.78	1	0.06	0.05	0.84	0.74
	1980	0.72	0.72	0.29	0.29	0.75	0.75
	1981	0.78	0.85	0.34	0.43	0.75	0.59
	1982	0.77	0.73	0.36	0.52	0.61	0.52
	1983	0.55	0.60	0.22	0.23	0.53	0.50
	1984	0.74	0.74	0.04	0.07	0.56	0.09
Kanzara	1979	0.62	0.89	0.24	0.26	0.42	0.01
	1980	0.66	0.86	0.29	0.37	0.36	0.03
	1981	0.69	0.85	0.23	0.24	0.39	0.09
	1982	0.65	0.81	0.09	0.06	0.50	0.10
	1983	-	-	-	-	-	-
	1984	0.42	0.62	0.13	0.12	0.15	0

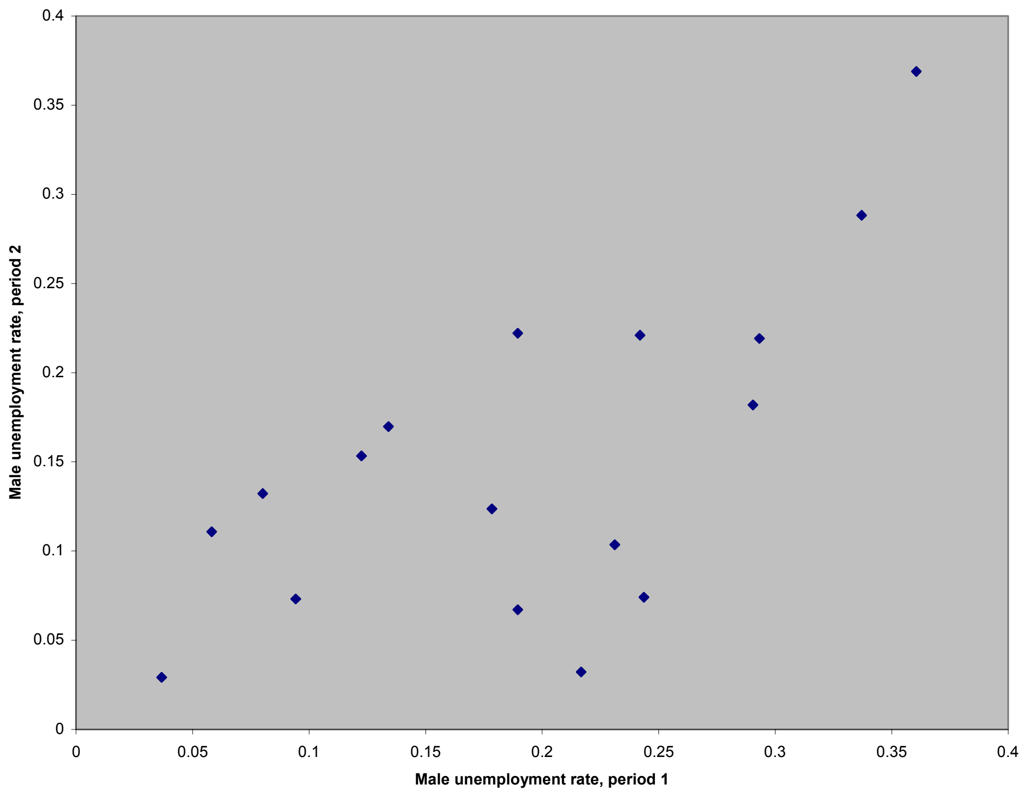
Note. Missing information for Kanzara for year 1983.

Appendix 12. Village-level Male and Female Off-farm Unemployment Rate,
Share of Off-farm Work in Total Work and
Share of Non-agricultural Work in Total Off-Farm Work in the Study Villages,
Kharif Season, Harvesting Period, 1979-84

Village	Year	Share of Off-Farm Work in Total Work		Off-farm Unemployment Rate		Share of Non-agricultural Work in Total Off-farm Work	
		Male	Female	Male	Female	Male	Female
Aurepalle	1979	0.51	0.82	0.22	0.18	0.49	0.03
	1980	0.64	0.73	0.22	0.25	0.27	0
	1981	0.41	0.80	0.12	0.11	0.25	0
	1982	0.59	0.84	0.15	0.20	0.29	0.08
	1983	0.34	0.75	0.13	0.10	0.02	0
	1984	0.47	0.85	0.07	0.05	0.76	0
Shirapur	1979	0.94	0.49	0.11	0	0.90	0.68
	1980	0.87	0.87	0.22	0.22	0.81	0.81
	1981	0.85	0.67	0.29	0.47	0.67	0.21
	1982	0.84	0.54	0.37	0.35	0.71	0.66
	1983	0.70	0.58	0.03	0.05	0.53	0.16
	1984	0.79	0.69	0.03	0.09	0.60	0.22
Kanzara	1979	0.69	0.82	0.07	0.15	0.32	0.008
	1980	0.56	0.84	0.18	0.18	0.29	0.06
	1981	0.67	0.77	0.10	0.17	0.41	0.13
	1982	0.67	0.75	0.07	0.08	0.46	0.02
	1983	-	-	-	-	-	-
	1984	0.54	0.68	0.17	0.20	0.19	0.03

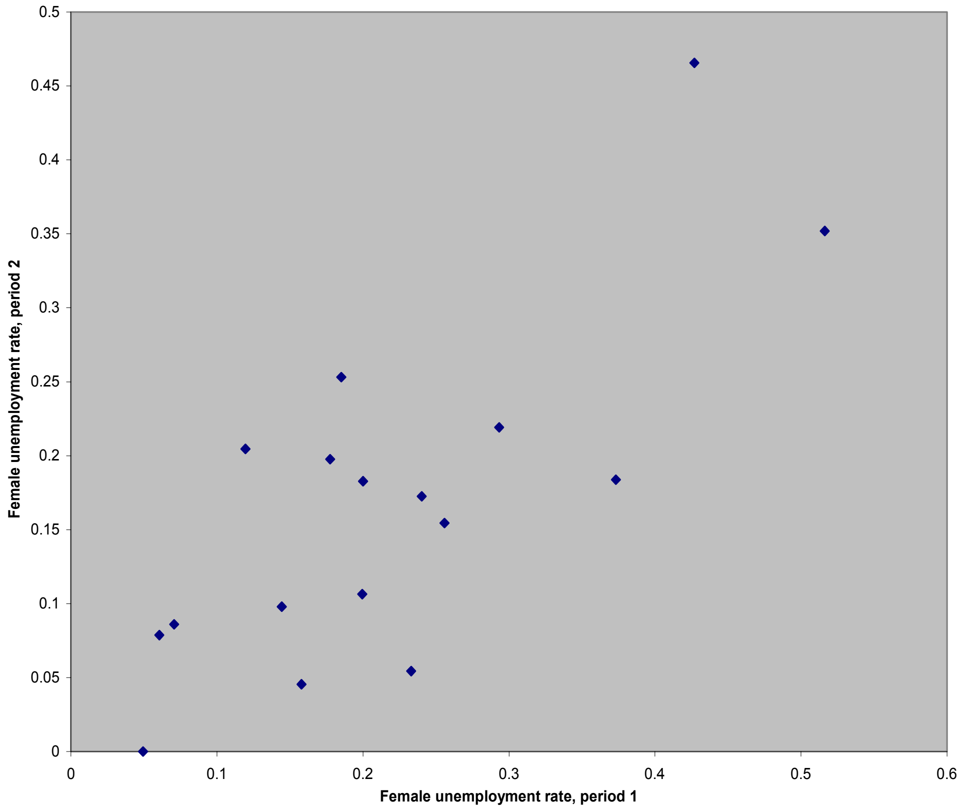
Note. Missing Information for Kanzara for year 1983.

Appendix 13. Village-level Male Off-farm Unemployment rates, Periods 1 and 2, *kharif* Season, 1979-1984, Scatter Plot.



Note. Male unemployment rate, period 2 in the vertical axis and male unemployment rate, period 1 in the horizontal axis (N=17).

Appendix 14. Village-level Female Off-farm Unemployment rates, Periods 1 and 2, *kharif* Season, 1979-1984, Scatter Plot.



Note. Female unemployment rate, period 2 in the vertical axis and female unemployment rate, period 1 in the horizontal axis (N=17).

Appendix 15. Correlations of Harvest Period Prices of Eleven Crops in the Study Villages, 1978-83

Year and Season	Crops in Price Series	Villages	Coefficient of Correlations (N=66)
1978-83 *Kharif* Season, Harvest Period Prices	Groundnuts Redgram(Tur)/Pigoenpea Chillies Rough dry fodder (crop by product) Fine dry fodder (crop by product) Crop by products not used as fodders but used as fuels ect. Other pulses Paddy (local variety) Greengram (mung) Jowar/sorghum (local variety) Jowar/sorghum (HYV)	Aurepalle and Shirapur	0.76 (<0.0001)[a]
		Aurepalle and Kanzara	0.57 (<0.0001)[a]
		Kanzara and Shirapur	0.82 (<0.0001)[a]

Note. [a]p-value for null hypothesis of no linear correlation in parenthesis.

Appendix 16. Summary Statistics of the Variables Used in Estimations of Chapter V

Variable(s)	N	Mean	Standard Deviation	Min.	Max.
Dummies					
Village: Aurepalle	467	0.377	0.485	0	1
Village: Shirapur	467	0.246	0.431	0	1
Village: Kanzara	467	0.377	0.485	0	1
Year: 1979	467	0.156	0.364	0	1
Year: 1980	467	0.173	0.379	0	1
Year: 1981	467	0.171	0.377	0	1
Year: 1982	467	0.163	0.369	0	1
Year: 1983	467	0.171	0.377	0	1
Year: 1984	467	0.165	0.371	0	1
Village-Year: Aurepalle 1979	467	0.059	0.238	0	1
Village-Year: Aurepalle 1980	467	0.064	0.245	0	1
Village-Year: Aurepalle 1981	467	0.069	0.253	0	1
Village-Year: Aurepalle 1982	467	0.064	0.245	0	1
Village-Year: Aurepalle 1983	467	0.062	0.242	0	1
Village-Year: Aurepalle 1984	467	0.058	0.237	0	1
Village-Year: Shirapur 1979	467	0.032	0.177	0	1
Village-Year: Shirapur 1980	467	0.043	0.203	0	1
Village-Year: Shirapur 1981	467	0.043	0.203	0	1
Village-Year: Shirapur 1982	467	0.036	0.187	0	1
Village-Year: Shirapur 1983	467	0.047	0.212	0	1
Village-Year: Shirapur 1984	467	0.045	0.207	0	1
Village-Year: Kanzara 1979	467	0.064	0.245	0	1
Village-Year: Kanzara 1980	467	0.067	0.249	0	1
Village-Year: Kanzara 1981	467	0.059	0.238	0	1
Village-Year: Kanzara 1982	467	0.062	0.242	0	1
Village-Year: Kanzara 1983	467	0.062	0.242	0	1
Village-Year: Kanzara 1984	467	0.062	0.242	0	1
Household Land Allocation(Acres)					
Total Crop Area	467	9.168	12.044	0.25	73.39
Total Owned Area	467	7.682	10.886	0	69.39
Total Leased-in Area	467	0.237	0.994	0	8
Total Sharecropped-in Area	467	1.249	3.844	0	29
Share of Owned Area	467	0.863	0.297	0	1
Share of Leased-in Area	467	0.030	0.142	0	1
Share of Sharecropped-in Area	467	0.107	0.270	0	1
Total Irrigated Area	467	0.965	2.180	0	17.7
Share of Irrigated Area	467	0.105	0.234	0	1
Group "High" Cropped Area	467	5.636	9.710	0	58.07
Group "Low" Cropped Area	467	3.509	4.595	0	27.35
Group "Undecided" Cropped Area	467	0.023	0.176	0	2.5
Difference of Land "Low" to "High"	467	-2.127	9.293	-48.6	23.2
Share of Land to "High" Crop	467	0.536	0.408	0	1
Share of Land to "Low" Crop	467	0.461	0.408	0	1
Share of Land to "Undecided" Crop	467	0.003	0.036	0	1

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Appendix 16. (Continued from the Previous Page)

Variable(s)	N	Mean	Standard Deviation	Min.	Max.
Household Crop Returns (in Rs., 1983 Constant Prices)					
Net Income	467	2894.936	5456.586	-4728.11	39026.24
Net Return	467	3859.449	6693.703	-3214.70	47158.43
Village Off-farm Labor Market Variables, Planting Period					
Male Unemployment Rate	438	0.192	0.087	0.037	0.361
Female Unemployment Rate	438	0.217	0.118	0.049	0.516
Male Share of Non-Agricultural Labor in Total Labor Demand	438	0.422	0.187	0.147	0.842
Female Share of Non-Agricultural Labor in Total Labor Demand	438	0.145	0.230	0	0.744
Male Real Wage Rate (Rs./Hr)	467	0.794	0.177	0.521	1.178
Female Real Wage Rate (Rs./Hr)	467	0.493	0.117	0.341	0.766
Monsoon Rainfall Uncertainty					
Standard Deviation, Monsoon Onset Date (in days)	467	11.394	4.095	7.324	16.509
Standard Deviation, Total Monsoon Rainfall (in mm)	467	174.878	20.449	155.574	208.262
(Village) Yearly Deviation, Total Monsoon Rainfall (in mm)	467	0.212	142.125	-182.8	280.738
Value of Household Non-financial Assets,1983 Constant Prices, Rs.					
Valuation of Assets	464	13842.71	14343.39	640	148315
Log of Valuation of Assets	464	3.955	0.397	2.948	5.253
Household Characteristics					
Number of Males Within Age 15-45	466	1.768	1.081	0	5
Number of Females Within Age 15-45	466	1.891	1.122	0	5
Number of Remittance Members	466	0.386	1.136	0	7
Dummy for Households Receiving Remittance	466	0.170	0.376	0	1
Education Level of Household Head	466	1.96	1.25	1	5
Dummy for Not Illiterate Household Head	466	0.451	0.498	0	1
Education Level of Female Principle Member	439	1.465	0.947	1	5
Age of Household Head	466	51.424	11.964	27	90
Age of Household Head, Squared	466	2787.352	1326.939	729	8100
Caste Index: Behrman	460	54.543	26.192	5	97.5
Price Ratios, Previous Harvest					
Groundnut-Jower/Sorghum (Local)	467	2.589	0.572	1.202	3.279
Jower/Sorghum (HYV)-Jower/Sorghum (Local)	467	0.877	0.125	0.591	1.186
Paddy (Local)-Jower/Sorghum (Local)	467	1.092	0.234	0.733	1.428
Chillies-Jower/Sorghum (Local)	467	2.815	1.772	0.707	6.063
Other Prices, Planting Period					
Urea Fertilizer, Constant Prices	467	2.489	0.289	2.057	3.049

Appendix 17. Random Effects Tobit Estimations with Male and Female Share of Non-agricultural Labor as Regressors

Random Effects Tobit Estimation *Dependent Variable: Land Share to "Low" Crop Group*				
Independent Variable(s)	Coefficient	Standard Errors	Z	Pr> |z|
Male Share of Non-agricultural Labor in Off-farm Labor Market	0.351	0.201	1.75	0.081
Regression No. 1 N= 438 Number of Households= 101 Log Likelihood= -381.804 Wald chi-sq= 3.05 Pr>chi-sq= 0.081				
Female Share of Non-agricultural Labor in Off-farm Labor Market	0.06	0.225	0.27	0.789
Regression No. 2 N=438 Number of Households=101 Log Likelihood= -383.242 Wald chi-sq= 0.07 Pr> chi-sq= 0.789				
Non-agricultural Labor Share: Male Female	 0.465 -0.2	 0.249 0.254	 1.87 -0.79	 0.062 0.431
Regression No. 3 N=438 Number of Households= 101 Log Likelihood= -381.485 Wald chi-sq= 3.58 Pr> chi-sq= 0.167				
Dependent Variable: Land Share to "High" Crop Group				
Male Share of Non-agricultural Labor in Off-farm Labor Market	-0.384	0.206	-1.86	0.062
Regression No. 1 N= 438 Number of Households= 101 Log Likelihood= -378.701 Wald chi-sq= 9.38 Pr>chi-sq= 0.0022				
Female Share of Non-agricultural Labor in Off-farm Labor Market	0.023	0.306	0.07	0.941
Regression No. 2 N=438 Number of Households=101 Log Likelihood= -382.249 Wald chi-sq= 2.08 Pr> chi-sq= 0.1494				
Non-agricultural Labor Share: Male Female	 -0.52 0.279	 0.249 0.281	 -2.09 1.00	 0.36 0.319
Regression No. 3 N=438 Number of Households=101 Log Likelihood= -377.042 Wald chi-sq= 4.38 Pr> chi-sq= 0.112				