Off-Farm Income, Risk, and Agricultural Production: A Case Study of Smallholders in India's Semi-Arid Tropics

M. Marrit van den Berg

Stellingen

1. Niet-agrarische groei in India's semi-aride tropen heeft een positieve maar beperkte invloed op agrarische groei door veranderingen in inputgebruik van kleine boeren.
   Dit proefschrift

2. Openbare werken verlagen het totale inkomensrisico van kleine boeren in India's semi-aride tropen sterk en beïnvloeden daardoor het gebruik van gewasinputs, maar hebben nauwelijks invloed op het inkomen uit gewasproductie.
   Dit proefschrift

3. Mathematics has no symbols for confused ideas.
   George Stigler

4. Niet alleen afhankelijkheid van extern gefinancierd onderzoek, maar ook een hoge publicatiedruk vormt een bedreiging voor de integriteit van wetenschappers.

5. De tendens om maatschappelijke organisaties the classificeren aan de hand van wat ze niet zijn (bijvoorbeeld non-profit organisaties en niet-gouvernementele organisaties) belemmert het inzicht in de rol van deze organisaties.

6. Bij je eerste vriend blijven is geen teken van risico-aversie maar van beginnersgeluk.

Stellingen behorend bij het proefschrift

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ABSTRACT

The purpose of the current study was to determine to what extent development of the nonfarm sector stimulates crop production and agricultural employment in India's semi-arid tropics (SAT). Two characteristics of India's SAT agriculture formed the basis for the study: i) that the major agricultural producers, smallholders, earn a significant part of their income outside their own farm, especially in the daily labour market; and ii) that crop production risk is high. As the farmers are risk averse and they have limited options to smooth consumption through changes in assets and liabilities, they try to stabilise income. This could result in the choice of crop production technologies that render relatively stable, but low yields. On the other hand, off-farm income may provide an alternative for stabilising income and ensure minimum consumption in all years. Hence, because they can earn off-farm income, farm households may be willing and able to increase crop incomes, even if this involves higher crop income variability from year to year.

The study shows that the labour market is extremely important in preventing farm households in India's SAT from experiencing very low incomes. Households actively adapt family labour supply to production risk. Much more important for income stability, however, is the flow of labour income that households earn independent of their risk preferences. As expected, production risk affects not only farm-household labour supply, but also the use of the major inputs in crop production: male and female labour and fertiliser use. Depending on the specific input and the production environment, risk appears to increase or decrease the use of a specific input.

The above suggests that the household labour endowment will affect crop input use and income from crop production. The first is true, given that there is sufficient year-round off-farm employment and not just employment during the agricultural growing season. In this case, households with a larger labour endowment feel less need to adapt the use of crop labour and fertilisers to production risk. However, these small changes in input use hardly seem to affect the magnitude and stability of crop income: the estimated input elasticities of the mean and variability of crop yields are low. Surprisingly, the household labour endowment thus has little effect on crop income.

Actual labour income may, however, still have a significant impact on net crop income: some farmers work longer hours than others do. Moreover, income from minor sources of off-farm employment, like nonfarm self-employment, may also affect net crop income. Empirical estimates show that the size and nature of the effect of off-farm income on net crop income depends on the characteristics of the income flow. Activities that require labour simultaneous to crop production and that have low returns on labour decrease net crop income. If the returns on the off-farm activity are certain and high relative to the casual farm wage, households will, however, simply substitute hired labour or capital for family labour. Moreover, they will use part of the off-farm income to intensify crop production. Finally, if the nonfarm activity becomes the main source of interest of the farm household, income from this activity will no longer affect crop production.

PREFACE

Working on a single project for five years is a long time. Writing this thesis sometimes felt like a never-ending project. However, most of the time I greatly enjoyed the work and appreciated the opportunity to develop my skills as a researcher. I have to thank many people for that. The struggle to complete this thesis could not have been the fruitful and mostly pleasant experience it was without their support.

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Marijke and Peter, thank you letting me share my frustrations with you, but most of all for your friendship. Annemarie and Gilbert, your door was always open for me, wherever it was. I hope that we will get to see more of each other now that we live in the same country.

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Marrit van den Berg
Wageningen, July 2001

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GLOSSARY OF SYMBOLS

A	vector of factors determining the inherent riskiness of land
B	loan taken
B_m	maximum loan
C	consumption
D	nonfarm labour demand
F	farm-household labour supply (to own farm production and the labour market)
$f(.)$	average planting-stage production
$g(.)$	harvest-stage production
$h(.)$	standard deviation of production
I	inorganic fertiliser
i	farm household
j	landless labour household
K	net planting-stage expenses
L	farm labour demand
ℓ	home time
M	total number of labour households in the village
N	total number of farm households in the village
p	output price
Q	crop production
R	landless labour supply
r	interest rate
S	savings
T	time endowment
t	stage
U	utility
w	wage rate
Y_e	landless exogenous income and planting-stage labour income
Y	full income
Z	household characteristics
α	coefficients of the mean production function
β	coefficients of the standard deviation function
ε	exogenous shock
γ	inherent riskiness of land
λ	Lagrangian multiplier for the borrowing constraint
μ	factor balancing village labour supply and demand in the harvest stage
ρ	time discount rate

ACRONYMS

CV	coefficient of variation
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
SAT	semi-arid tropics
SD	standard deviation

1. INTRODUCTION

1.1. Statement of the problem

Parts of Indian agriculture have been influenced by the Green Revolution over the past three decades. High-yielding varieties have been introduced, combined with the timely use of inputs such as fertiliser and irrigation. However, the increases in output have not been spread evenly over the country. Among the main beneficiaries are larger landholders in the irrigated Indo-Gangetic Plain. Although more than 70% of Indian cropland is cultivated under dryland conditions, irrigated agriculture has commanded the lion's share of agricultural research resources (Walker and Ryan, 1990). Consequently, the Green Revolution has largely bypassed areas with limited opportunities for irrigation, like the semi-arid tropics (SAT). The result is that SAT agricultural productivity is stagnating.

Nonetheless, SAT agriculture provides a livelihood for more than 250 million people, either as cultivator households or as landless labourers (Walker and Ryan, 1990). Most of these people are very poor, and their number is ever increasing: population growth averaged 1.8% for 1990-97 (EIU, 1998). The nonprimary sectors currently support only 30% of the Indian population, and growth is not fast enough to increase this percentage rapidly. Moreover, high-growth industry is concentrated in three main areas: around Mumbai; around Delhi; and the corridor from Bangalore to Chennai (EIU, 1998). Consequently, agriculture has to absorb the bulk of population growth in most parts of India, and continuous efforts are needed to stimulate agricultural development. As Ashok Gulati from the International Food Policy Research Institute puts it according to the Economist (2001): 'Agriculture has become a parking space for the poor. The was out of poverty is faster agricultural growth, which would raise farmers' incomes and increase the demand for locally produced goods and services, drawing labour away from farming.'

The main determinant of agricultural production in India's SAT is the high variability of rainfall. The resulting yield uncertainty is the major source of income risk for farm households: at the start of the growing season, farmers can predict harvest prices in a nearby market much more accurately than they can predict yields in their own fields (Walker and Ryan, 1990). The households' capacity to smooth consumption is limited (Townsend, 1994). Consequently, households try to limit exposure to income shocks that can be handled with the means available (Morduch, 1995). One way to do so is to select secure production techniques, but this usually implies a low average crop income.

Risk affects agricultural production not only directly, but also indirectly through its effect on financial markets. Uncertainty causes informational asymmetries between borrowers and lenders: the lender cannot control the activities of the borrower. In reaction, lenders demand collateral and ration credit (*e.g.*, Hoff and Stiglitz, 1990; Stiglitz and Weiss, 1981). The covariate character of agricultural risk further decreases the efficiency of rural credit markets. Empirical evidence on credit constraints in India's SAT is mixed. Farmers have very little access to long-term credit, while short-term credit is widely, but maybe not sufficiently, available. Risk may not only decrease the supply of credit, but also the demand for credit: prudent consumers may be reluctant to borrow (Deaton, 1997).

Farmers in developing countries do not depend on agricultural production alone for their livelihood. Smallholders acquire a significant part of their income outside their own farm (*e.g.*, Reardon (1997) for 17 African countries, and Ruben and Van den Berg (2001) for Honduras). This is no different for India's SAT, where only large-farm households rely mainly on agricultural income. For both landless and small-farm households, wage income from the daily labour market is the largest single income source (Townsend, 1994). Other, less important, off-farm income sources are the long-term labour market, nonfarm self-employment, and remittances.

Off-farm income may have a strong impact on the agricultural production decisions of households facing risk and credit constraints. It is an important source of cash income, which can improve farm productivity if it is used to finance farm-input purchase or longer-term capital investments. Moreover, off-farm income may help reduce the variance of overall household income and improve food security by allowing the household to buy food in cases of yield shortfalls (Reardon, 1997). Households may then be able to increase the riskiness and profitability of their agricultural activities.

Investment of off-farm income in agriculture is, however, by no means automatic. Beyond the relative profitability and riskiness of agriculture, at least two sets of variables affect the investment decision. The first is the nature of the capital market: nonfarm income may serve either as a substitute or as collateral for credit. The second is the characteristics of the nonfarm income flow. This includes the timing as well as the interhousehold distribution (Reardon *et al.*, 1994).

These issues have received only limited empirical scrutiny. Previous research shows that wage income is actively used to manage risk in India's SAT (*e.g.*, Kanwar, 1991; Kochar, 1995). Little attention has, however, been paid to the production and investment effects of labour income. Off-farm income is sometimes included as an explanatory variable in regressions of the decisions of farm households (Kelly, 1988; Savadogo *et al.*, 1994; Woldehanna, 2000). However, this does not shed light on the workings of the underlying decisions and constraints. Off-farm income is not exogenous to the household, but an integral part of a decision-making process in which the household considers relative profitabilities, risk management, and liquidity (De Janvry, 1994; Reardon *et al.*, 1992). Only by considering farm-household decisions within this context can we reveal the exact impact of off-farm income on agriculture in specific circumstances.

The present study unravels the interactions between off-farm income and agricultural production in a high-risk environment with strongly seasonal production activities. It focuses on short-run production decisions alone and ignores the potential relation between off-farm income and on-farm investment, which is considered by, *e.g.*, Savadogo *et al* (1994) and Reardon *et al* (1994). An analytical model was developed that reveals the underlying decision processes of family labour supply and crop input use. Empirical estimates were used to test the relevance of the model and the impact of the different options and constraints in two villages in India's SAT. Moreover, the study indicates the impact of off-farm income from different sources on income from crop production. The results provide food for policy recommendations: if well-functioning labour markets and nonfarm self-employment allow households to increase agricultural production and profits, labour market and nonfarm development policies can be considered as possible stimulants of agricultural development.

1.2. Research questions

Farm household theory states that household production decisions are independent of their consumptive preferences when all markets are perfect and there are no transaction costs. The use of labour in crop production is in this case independent of the household's labour endowment (Singh *et al.*, 1986a). However, if labour is not actively traded in the market, households with a larger labour/land ratio will use more labour-intensive technologies than other households do (Benjamin, 1992).

Even when labour markets are perfect, imperfections in other markets will cause the labour endowment to affect crop technology choice. Households facing risk and credit constraints may use labour income to alleviate both. Cropping-season wages may serve as a consumption floor and as a substitute for credit. Moreover, households can increase their engagement in off-farm activities when yields turn out to be low. Hence, we may expect that the household labour endowment will play an important role in the agricultural decisions of farm households in India's SAT, even though, or, on closer inspection, just because, labour markets function well in this area.

Insight into the relation between wage employment and crop production is important as it may reveal the possible use of (nonfarm) labour market policies for stimulating agricultural development. Although well-functioning rural labour markets are important characteristics of India's SAT, there is significant dry season unemployment. Unemployment rates vary considerably across regions. The data used in the present study comes from two villages with different labour market conditions: Aurepalle and Kanzara. In contrast to Kanzara, employment possibilities are limited in the dry season in Aurepalle. This restricts the use of the labour market for risk management in the latter village, and allows detection of the impact of dry-season employment on cropping season decisions. Moreover, the behaviour of the households studied, especially those in Kanzara, shows some of the (indirect) benefits of employment programmes in areas with relatively short cropping seasons and a significant dry-season labour surplus.

In the current study, an analysis was made of how households cope with risk and possible credit constraints, and how they use off-farm employment possibilities in this respect. Therefore, the various chapters deal with the impact of off-farm employment possibilities on the demand for labour and fertilisers in crop production and on per capita household income. For farm households, the ultimate outcome of their decisions regarding resource allocation is household income, either in cash or in kind. Off-farm employment possibilities, of course, increase household welfare by offering an additional source of income. Moreover, such possibilities can increase the households' capacity to maximise crop profits in the presence of risk, as argued above. The size of the total effect of off-farm employment on farm-household income is yet unclear.

Farm income is, however, not the only outcome of production decisions: the demand for inputs directly affects the village economy. Smallholders' labour demand provides the bulk of employment in India's SAT. Unless employment growth keeps pace with population growth, the number of people living in poverty will increase significantly in the coming years. In addition, fertiliser use is important for sustainability. Currently, many SAT farmers mine their soils (Randhawa and Abrol, 1990). As the availability of manure is limited (Walker and Ryan, 1990), enhancing fertiliser use is required to counter the process of soil mining.

Summarising, in the current study, an analysis is made of the impact of family labour on crop production when yield risk is high and credit markets are imperfect. The following issues were given special attention:

- How do risk and credit constraints affect farm-household labour supply?
- How do risk, credit constraints, and the family labour endowment affect the use of the major crop inputs: labour and fertilisers?
- How do risk, credit constraints, and the family labour endowment affect crop profits and per capita household income?
- What is the specific impact of the different sources of off-farm income on net crop income?

1.3. Outline of the study

Despite imperfections in risk and credit markets, farm households in India's SAT operate in an environment with well-functioning labour markets. This market environment is discussed in depth in **Chapter 2**, which introduces the two study villages and the survey households. This specific market environment and some methodological considerations form the basis of the approach followed in the rest of the study.

Chapter 3 presents the basic model used: a two-stage farm-household model covering a single agricultural year. In the planting stage, yields are uncertain and the household decides on current-period family labour supply and crop labour use. Credit constraints may limit household decisions. In the harvesting stage, the standing crop is harvested, and the household allocates labour under certainty. The model reveals how households can use family labour to mitigate the effects of yield risk and short-term credit constraints. Households can work long hours in the planting stage to secure sufficient liquidity and to guarantee a certain amount of income (*ex ante* risk management). Moreover, they can increase their harvest-stage workload when yields turn out to be low (*ex post* risk coping). Empirical estimates confirm the active use of family labour for risk management, but they do not demonstrate the presence of short-term credit constraints. The empirical analysis introduces a risk measure from the production literature into a model of farm-household behaviour. Past household studies used time series of income or production to estimate risk (*e.g.*, Saha, 1994, Kanwar, 1991). These measures do not accurately measure risk as perceived by the farm household, which has more than just historical information at the start of the cropping season. The measure used in the current study includes as much of this information as possible.

The implications of family labour as a risk management tool for farm input use are considered in the next two chapters. **Chapter 4** focuses on labour use decisions, examining the determinants of labour use within the context of the model presented in Chapter 3. Since both crop labour use and the family labour endowment affect income risk, the size of the family labour endowment may have a strong impact on agricultural labour use. This is important at the aggregate level, since agricultural employment is the major income source of the rural poor. To prevent an increase in poverty, employment growth should keep pace with population growth. In addition, seasonal employment fluctuations may have serious effects on household welfare. Consequently, India and other countries such as Pakistan and Bangladesh have adopted public-works programmes to provide employment during the slack season. The model indicates that these programmes will affect the capacity of smallholders to manage production risk and, therefore, their decisions on the use of labour in crop production. In other words, public-works programmes will affect agricultural employment. The empirical estimates confirm this hypothesis. The availability of year-round off-farm employment allowed the survey households to use family labour for risk management, which decreased the need to use crop labour for managing production risk. Planting-stage employment alone was not enough to produce this effect. Depending on crop technology and the biophysical environment, the availability of dry-season employment can imply an increase as well as a decrease in the use of labour. Moreover, wage income is likely to increase the availability of liquid assets at the beginning of the cropping season. As prudent households are hesitant to borrow, an increase in liquidity implies a rise in the use of crop labour.

Smallholders' fertiliser use is dealth with in **Chapter 5**. Agricultural production is only sustainable if farmers replace the nutrients that are extracted through the cultivation process. This is not the case in the study area. Fertiliser use is low and many farmers do not use fertilisers at all. Although more and more farmers are applying inorganic fertilisers on their dryland crops, fertiliser use is still too low to prevent soil nutrient mining (Randhawa and Abrol, 1990). Manure is a not an alternative. The amount of fodder available limits the number of livestock that farmers can keep, and high transportation costs impede the purchase of manure in the market (Walker and Ryan, 1990). Accordingly, a significant increase in the use of organic fertilisers is not feasible in the medium run, and boosting fertiliser use must be part of a strategy to counter the process of soil mining. Empirical estimates for the two study villages reveal that farmers increased fertiliser use in response to risk. The introduction of alternative methods of risk management will, therefore, lead to a decrease of fertiliser use.

Consequently, public-works programmes, although valuable, cannot be used to promote smallholder fertiliser use.

In **Chapter 6,** the estimates from Chapters 3-5 are used to simulate household behaviour with respect to crop production and labour supply. The results indicate that *ex ante* risk management and *ex post* income smoothing through family labour supply were effective risk strategies. Their main result was an increase in minimum income. Much more important for income stability was, however, the stable flow of labour income that households earned independent of their risk preferences. Moreover, the simulations show that the impact of changes in input use on household income was limited. As the estimated input elasticities of mean output were low, a change in input use translated into a much smaller change in output. The input elasticities of output variance were also moderate. Hence, although the family labour endowment significantly affected input use in one of the two study villages, its effects on the simulated level and variability of crop income were small.

Finally, in Chapter 6, the possible impact of stochastic harvest wage rates is discussed. Production risk may lead to uncertainty of harvest-stage wage rates, as village labour markets are insular and crop production provides the bulk of employment. If yields are highly covariate, farm households will face low crop income and low harvest wage rates at the same time. If this were the case in the study villages, the simulations would overestimate the stabilising impact of family labour. Simulations of labour market equilibria at different yield shocks, however, reveal that harvest wage rates were quite predictable and largely independent of the yield shock. Accounting for the stochastic nature of wage rates did, therefore, hardly affect the results of the simulations of household behaviour.

In **Chapter 7**, the specific impact of various sources of off-farm income on net crop income is examined. This chapter, therefore, takes a somewhat different perspective than the previous chapters and deviates from the formal model presented in Chapter 3. Farm households are still considered utility maximising units, but they can now choose between a number of farm and off-farm activities. Besides crop production, the analysis considers six income-generating activities: casual farm employment, casual nonfarm employment, regular employment, nonfarm self-employment, livestock production, and transfers. These six activities differ with respect to timing, profitability, and access barriers, and may therefore have a different impact on crop production. A regression of net crop income on agricultural resources and the various noncrop incomes confirms the diversity of the effects of different noncrop income sources. It appears that income from off-farm activities stimulates crop income as long as the activity is relatively profitable but does not become the main interest of the farm household.

The findings reported in the previous chapters are combined in **Chapter 8**. Together, they give a comprehensive picture of the role of labour endowment and off-farm income in rural development in India's SAT. This picture demonstrates how labour market interventions can stimulate agricultural and rural development. Moreover, the chapter puts the findings of the study into the perspective of development theory.

The study provides several contributions to the literature. First, it presents a framework for studying the use of family labour for *ex ante* risk management as well as *ex post* income smoothing. The empirical measures utilised are more precise than the risk measures used in previous studies. Previous research considers *ex ante* risk management and *ex post* risk coping separately, but not as a joint strategy. Joint evaluation of the use and impact of the two strategies suggests that ignoring the *ex ante* strategy and, to a smaller extent, the *ex post* strategy, does not much affect the results of studies on farm-household behaviour in India's SAT. The latter strategy significantly decreased the impact of yield shocks on total household income. Paradoxically, this affected the use of inputs in crop production, but not the magnitude and variability of crop income.

Second, the current study distinguishes empirically between the impact of risk and credit constraints on crop input use. It shows that short-term credit constraints did not affect household behaviour, while production risk involved adaptations in the level of labour and fertilisers used. Again, these adaptations appear to have had a negligible impact on both the variability and magnitude of crop income.

Finally, the study looks into the direct effects of various sources of off-farm income on income from crop production. Off-farm income sources differ with respect to capital requirements, timing, and risk, and may, therefore, affect crop income differently. Although the literature recognises the importance of the nature of the off-farm income stream, these aspects have received little empirical scrutiny.

2. STUDY VILLAGES AND METHODOLOGY

This study uses data from two villages in India's SAT which were collected by resident investigators of ICRISAT during the period 1975-1984. The villages represent two distinct agro-ecological zones. Aurepalle is located in the drought-prone district of Mahbubnagar, while Kanzara is situated in rainfall-assured Akola. Both the average productivity and the stability of yields were lower in Aurepalle than in Kanzara. The Kanzara labour market was buoyant owing to the favourable production environment and the presence of a public-works scheme. In Aurepalle, labour markets were competitive during the cropping season, but there was high unemployment during the dry season. Farm households in both villages were plagued by production risk and had limited capacity to smooth consumption from year to year. The basic methodology used for analysing these data was farm-household modelling.

2.1. Indian development and SAT agriculture[1]

Between 1956 and 1990, India followed a strategy of industry-led development based on the Soviet experience. In the early fifties, Indian agriculture was already suffering from heavy population pressure on land. Labour productivity was much higher in manufacturing than in agriculture, and the income elasticity of demand for industrial goods exceeded that for agricultural products. The idea was that rapid industrialisation and expansion of markets would boost trade and commerce, transportation, banking and finance, etc. The government focussed policies on heavy industries producing basic machines and metals. The idea was that these industries would help the economy to build up a large volume of capital stock at a relatively fast rate. In order to achieve self-reliance, the government opted for a protectionist path and encouraged import-substitution.

Although real per capita income doubled between 1950 and 1990, this did not lead to the elimination of poverty. Between 1974 and 1990, the number of people living in poverty declined at an annual rate of 2.7 % in the rural sector and 2.2 % in the urban sector. Nevertheless, in the early nineties, over one third of all Indians still lived below the poverty line. The absolute number of poor increased, and income and wealth became increasingly concentrated in the hands of the propertied class.

In 1991, the government introduced a new development strategy emphasising privatisation and liberalisation. Most policy measures were directed at the corporate sector, which accounted for only 10% of GDP. The new policies boosted GDP growth, but there has been debate about their impact on poverty. Influential scholars argued that there was a slowdown in the rate of poverty reduction, as the expected automatic transmission of the benefits of production growth to the poor did not materialise. They contended that the link between growth, employment, and poverty reduction depends crucially upon the pattern of growth. This pattern concerns the economic sectors in which growth takes place and the degree to which the disadvantaged segments of the population and the backward regions of the country are successfully integrated into the wider growth process. This point of view is controversial, but has significantly influenced Indian politics.

Since 1996, special consideration has been given to agriculture. Although the share of agriculture in GDP decreased from 53% in 1960-61 to a mere 26% in 1997-98, agriculture remains the backbone of the Indian economy. Agricultural commodities amount to 50% of exports, while manufactured goods with a substantial agricultural content contribute another 20%. Moreover, around 65% of the total workforce is employed in agriculture. However rapidly new industries develop, they will not be able to provide adequate employment for the ever-growing population in India. Increased employment will, therefore, also have to be found in agriculture or in rural industries.

The growth rate in agricultural production has been highly skewed in terms of geographic areas and crops. Regions that are well endowed with resources (like Punjab, Haryana, and Western UP) have benefited much from the use of modern green revolution technology, while other regions have remained backward and underdeveloped. Reduction of regional disparities requires giving special attention to these areas.

The large dryland areas of India's SAT form an important part of the country that has been largely bypassed by the green revolution. The SAT are those tropical regions where rainfall exceeds potential evapotranspiration in four to six month of the year. Mean annual rainfall ranges from about 400 to 1,200 mm. India's SAT includes much of the peninsula (see Figure 2.1). The salient agricultural characteristics of the SAT are rainfall uncertainty, synchronic timing of operations, and covariate production risk. Nevertheless, India's SAT are vast and the production environment is diverse. Soils are heterogeneous, and the rainfall regime differs between various regions and districts. Cereal production performance varied considerably from district to district within the dryland SAT states, but generally lagged far behind what had been obtained in the irrigated Northwest.

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[1] This section is based on Datt and Sundaharan (2000).

The remainder of this chapter elaborates on the setting of the study and the methodology used. Section 2.2 introduces the ICRISAT village-level studies, part of which is used in the present study. Section 2.3 presents the main characteristics of the survey households, while section 2.4 elaborates on the village environment in which these households operate. Finally, section 2.5 introduces the theoretical framework used: farm-household modelling. Special attention is paid to methods to estimate farm-household models.

2.2. The ICRISAT village-level survey[2]

2.2.1. Selection of the study villages

In 1975, the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) initiated the now influential village-level studies on backward SAT agriculture. ICRISAT selected three contrasting dryland regions, based on cropping systems, soil conditions, and climatic criteria. Within each region, ICRISAT chose a representative district, and within each district, they selected two typical villages for in-depth investigations. In selecting the villages, ICRISAT kept in mind the specific characteristics conditioning district selection and took care that the villages were not located near larger towns or on paved roads. Villages with special government programmes or direct outside resources, such as those where private voluntary organisations were active, were also not considered. About the representativeness of the selected villages, Walker and Ryan (1990) state:

> We believe that some of the findings reflect what is happening nationally, most apply to the study regions, while a minority are unique to the villages.

The regions selected were the Telengana region in Andhra Pradesh, the Bombay Deccan in Maharashtra, and the Vidarbha region also in Maharashtra. Districts representative of those regions included Mahbubnagar in the Telengana region, Sholapur on the Bombay Deccan, and Akola in the Vidarbha region (see Figure 2.1). The main agricultural characteristics of these regions are given in Table 2.1.

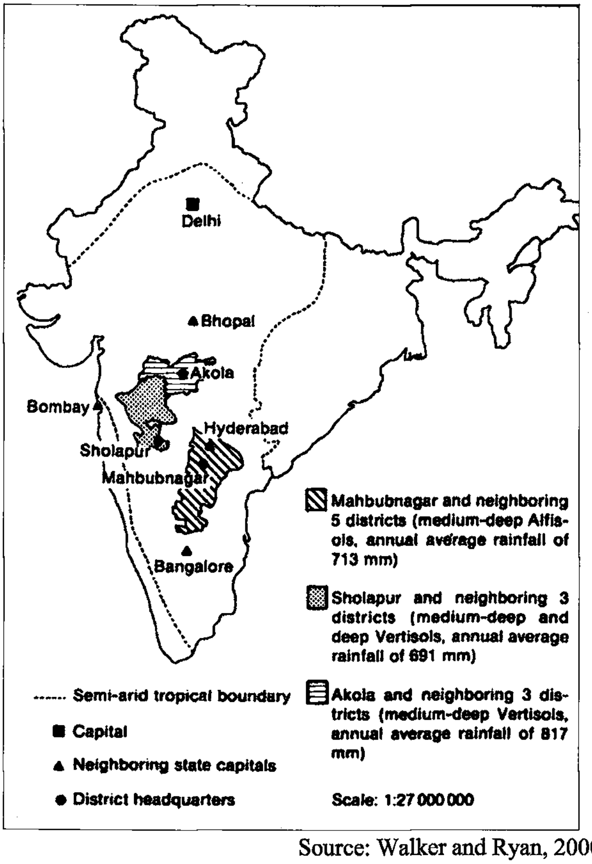
[2] Unless stated otherwise, the information in this section comes from Walker and Ryan (1990).

Table 2.1. Soil, rainfall and crop characteristics of the ICRISAT study regions

	Mahbubnagar	Sholapur	Akola
soils	Red soils (alfisols); low water-retention capacity	Deep black heavy clay soils (vertisols); high water-retention capacity	Medium deep black clay soils (inceptisols/'medium-deep vertisols'); medium water-retention capacity
rainfall[a]	Unassured, 630 mm, 31% CV	Unassured, 630 mm, 22% CV	Assured, 890 mm, 22% CV
major crops	Kharif, or rainy season, sorghum, castor, pearl millet, paddy, pigeon pea, groundnut	Rabi, or post-rainy season, sorghum, pigeon pea, minor pulses	Cotton, sorghum, mung bean, pigeon pea, wheat

Note: [a] The mean rainfall estimates and their coefficients of variation (CVs) in percent refer to ten annual observations collected in one study village in each region from 1975/76-1984/85.

Source: Walker and Ryan (1990)



Source: Walker and Ryan, 2000

Figure 2.1. India's SAT and the survey districts

The districts span much of the diverse growth experience in cereal production within India's dryland SAT. In the rainfall-assured but little irrigated Akola region, growth was relatively high (3.5%) and easily outpaced population growth; in the more heavily irrigated but rainfall-unassured Mahbubnagar district, cereal production growth was just high enough to compensate population growth (1.5%); and in the drought-prone Sholapur region, cereal production has stagnated (0.3%).

Data collection started in 1975 among 40 sample households in two villages in each district. In 1978, data collection was stopped in one village per district, mainly because of similarity between two nearby villages. In the remaining three 'continuous' villages, data collection continued until 1984.

Data from only two of the continuous villages, Aurepalle in Mahbubnagar and Kanzara in Akola, were used in the present study. There were two main reasons to exclude the third village, Shirapur in Sholapur district. Most important, data on family labour allocation, which are essential for this study, are incomplete for Shirapur (Townsend, 1994). Moreover, the potential for agricultural development of the region is very limited. Rabi (or post-rainy season) sorghum is grown on 42% of the gross cultivated area. Farmers use this traditional cropping system to cope with the high uncertainty of the onset of the southwest monsoon. They store rainfall in their soils during the rainy season and cultivate sorghum under a regime of receding soil moisture during the post-rainy reason. Alternatives that are more profitable are not available.

2.2.2. Data

ICRISAT drew a sample of 10 landless and 30 cultivator households in each study village. In the present study, only the data for the cultivator households, which were defined as those operating more than half an acre (0.2 ha), were used. ICRISAT stratified the cultivator households in each village according to operated farm size into three equally numerous groups (see Table 2.2). They drew a random sample of ten households from each tercile. Over time, households left the sample and switched between the landless and the cultivator groups. New households from the same (original) landholding class replaced the households that were dropped from the sample.

Table 2.2. Farmsize groups in the study villages: landholding terciles in 1975

	Aurepalle	Kanzara
small	0.2-1.2	0.2-1.8
medium	1.2-3.2	1.8-5.3
large	>3.2	>5.3

Annually, the resident investigators updated information on the composition of the household, land use, credit and debt, stocks, livestock, implements and machinery, and farm buildings. As in most studies, the data on credit is limited: the data files contain only information on credit use, not on demand (Singh *et al.*, 1985). On the other hand, land use data is very extensive. For each plot, data was collected on various soil characteristics (*e.g.* type, depth), irrigation status, and the (combination of) crop(s) cultivated.

With three-to-four-week intervals, resident investigators collected data on household transactions, family labour and draught power utilisation, and crop cultivation. Crop cultivation data cover detailed data on the amount and type of inputs used. Labour use was classified into four main categories: family male, family female, hired male and hired female labour. Besides the category, the activity is specified: *e.g.*, weeding, harvesting or ploughing. The type of fertiliser was registered, so that the content of nitrogen, phosphorus and potassium can be calculated.

Detailed data on family-labour allocation were collected only during the second half of the survey. For 1975-1978, the researchers collected day-before-interview recall data, not time aggregates. Since 1979, however, the data files contain information about wage earnings, individual labour supply to own farm production, casual and regular wage employment, and involuntary unemployment. The current study, therefore, uses the entire sample for estimation whenever possible, and the years 1979-1984 whenever labour supply data are needed.

Not all data are equally reliable and consistent. Consumption data are noisy, as not all consumption categories were collected in all years (Townsend, 1994). Moreover, data on the use and supply of family labour was collected in multiple schedules. First, the plot cultivation schedule (SP) provides information on family labour used per crop activity. Second, the labour utilisation schedule (SL) provides information on the supply of family labour supply to own production and to three types of casual markets. Finally, the household transaction schedule (ST) provides information about the supply of family labour to the casual and the regular labour market. The information of these various schedules is not always consistent. Family labour used in the different production activities (SP) does not sum up to total family labour supplied to their own farm (SL). Moreover, the supply of labour to the different casual labour markets (SL) does not sum up to total casual labour supply (ST). For the current study, the data from the most detailed records, *i.e.*, data on own-farm family labour from the plot cultivation schedule and data on casual labour supply from the labour utilisation schedule, are used.

2.3. The survey households

2.3.1. Population profile

The study villages are small: in 1975, 476 households lived in Aurepalle and 169 in Kanzara. Although fertility declined, the population was still growing by the end of the 1980s. Natural growth was the main source of change in the number of village inhabitants. The bulk of migration was comprised of the wife moving to the husband's village, often from a nearby village. Moreover, every year a few households, usually landless labourers, settled in Kanzara.

Most of the village households are caste Hindus. In each village, one can find many separate caste affiliations. The dominant castes are traditionally farmers: the Reddis in Aurepalle and the Malis and Maharathas in Kanzara. Somewhat lower on the hierarchical ladder are families belonging to the different service castes who are employed as herder, carpenters, blacksmiths, barbers, water carriers, washermen, goldsmiths, etc. They often engage in agriculture beside their traditional caste activity. Harijans, or former untouchables, make up 10 to 25 percent of the village population. Many of them belong to the group of landless labourers. The caste hierarchy is not static: some castes perceive themselves in ascendancy and others in decline.

Although caste strongly affects many aspects of village life, its effects are often overshadowed by other considerations (Binswanger and Singh, 1988):

> Lower caste (adjusted for parental education) leads to lower education, indicating either poor access of low caste individuals to the education system or poorer commitment to education. Similarly, caste sharply affects how much inheritance an individual receives. In sharp contrast, however, once a person has been given his or her endowment in terms of inheritance and schooling, caste does not strongly affect their individual performance, *i.e.* caste and ability do not seem to be correlated. Nor does it appear that an individual's performance in the private economy of the villages is constrained by caste.

During the survey, over 95% of the village households relied heavily on agriculture, either as cultivators or as landless labourers. The remaining few percent were full-time village artisans, shopkeepers, and traders. About one third of the agricultural households were labour households. Labourers comprised, however, only about one quarter of the agricultural population because their mean family size was less than that of cultivator households.

About one-half of the sample households were nuclear; four-tenths were stem, in which one or both parents reside with their son's family; and one-tenth were joint-stem, in which parents reside with more than one married son. The incidence of extended families did not differ much between the villages, but increased gradually as the sample aged over the research period. This supports the view that 'jointness' is primarily determined by the lifecycle.

The vast majority of village households were very poor, even compared to all-India averages. Annual median income per capita was Rs 400 in Aurepalle as compared to Rs 700 in Kanzara over the study period (1975 prices). This was equivalent to around US$50 and US$85. Based on a poverty line of a monthly per capita expenditure of Rs 15 in 1960/61 prices, about three fourths of the households fell below the poverty line. The parity in average income between the landless labour and the cultivator group is striking. Only the highest tercile of landholders enjoyed significantly higher per person income compared to the rest of the village. Nevertheless, even some households with large landholdings fell below the poverty line from 1976/77 to 1981/82.

Many village households saw their prosperity increase during the period of analysis from 1975/76 to 1983/84. The poorer households in the mid-1970s experienced as much or more growth in real per capita income as the richer households. Holdings of consumer durables and financial assets increased. However, although many households moved up and down in the village income profile over time, income inequality remained about the same in both villages.

2.3.2. Income composition

The survey households earned income from various sources: crop production, livestock, wage employment, self-employment, and transfers (see Table 2.3). In both villages, crop production and wage employment were by far the most important sources of income: large farmers generally earned most of their income with crop production, while small farmers depended largely on wage income. Most households derived some income from the sale of livestock, especially goats. Except for shepherd households, livestock production was, however, less important than crop or labour income. Income from nonagricultural self-employment did not figure heavily in household income for the vast majority of households, with the exception of some toddy (palmwine) tappers in Aurepalle.

Income variability was substantial, especially in drought-prone Aurepalle, where the average coefficient of variation of household income was somewhat over 40% (see Table

2.3). Income transfers were of only minor importance for the study households. These transfers had little effect on total income stability. Nevertheless, household income was considerably less volatile than farm income. This implies that off-farm income stabilised total household income, despite the high coefficients of variation for the individual income sources.

Table 2.3. Income composition and variability (1975-1984)

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
total income (Rs)	3296	5526	13269	5590	6222	20178
	(0.42)[a]	(0.45)	(0.41)	(0.23)	(0.31)	(0.31)
crop share	0.15	0.35	0.62	0.30	0.49	0.66
	(0.76)	(1.08)	(0.61)	(0.62)	(0.52)	(0.38)
livestock share	0.09	0.17	0.32	0.05	0.13	0.23
	(1.15)	(0.98)	(0.55)	(1.14)	(0.90)	(0.59)
wage share	0.47	0.19	0.04	0.57	0.34	0.11
	(0.66)	(0.98)	(1.08)	(0.31)	(0.52)	(1.30)
nonfarm self-employment share	0.28	0.31	0.06	0.07	0.04	-0.01
	(-0.70)	(0.57)	(0.36)	(-0.12)	(7.73)	(-2.42)
transfer share	0.01	-0.01	-0.04	0.01	0.00	0.00
	(1.98)	(1.69)	(2.13)	(1.78)	(1.81)	(1.88)

Note: [a] median intra-household coefficient of variation for the level of income in parentheses.

2.4. The village environment

The study villages represent distinct agro-ecological zones. Aurepalle is located in the drought-prone district of Mahbubnagar in Andhra Pradesh. Soils are heterogeneous: at the finest level of classification, farmers recognise twenty-one soil categories. Most soils can, nevertheless, be broadly classified as red alfisols. Kanzara is situated in the relatively rainfall-assured, homogeneous black-soil district of Akola in Maharashtra. The villages are predominantly dryland, but irrigation is not unimportant in Aurepalle. During the survey period, around 10% of the cultivated area was under irrigation in this village, compared to 3% in Kanzara.

The major cropping season, kharif, starts with the coming of the southwest monsoon, late June and early July. Harvesting extends from September into January, depending on the crop. The cropping pattern is diverse, but the most common systems are hybrid sorghum and cotton intercrops in Kanzara, and cereal/pulse intercrops, castor and paddy in Aurepalle. Significant technological progress has been made in both villages, especially in paddy production in Aurepalle and sorghum in Kanzara.

The main agricultural inputs are labour and bullock draught power. Fertiliser use is low but increasing. Especially in Aurepalle, farmers have applied fertilisers disproportionately to irrigated area. Nevertheless, the picture is changing, and more and more farmers also apply fertilisers on their dryland crops.

The demand for bullocks is highly covariate, as most activities have to be executed within a fairly narrow time frame. Soil preparation must be finished before the soil becomes too dry in the case of red soils in Aurepalle or too unworkable on the heavier clay soils in Kanzara. This inhibits the development of a rental market. Nevertheless, some small farmers hire draught power. Single bullock owners in Aurepalle often pool their bullocks into teams and cultivate land on an exchange basis. Alternatively, they pool their bullocks with cows or buffaloes.

Farmers consider male and female labour as separate inputs, for all pre-harvest activities are gender-specific. The most important female activities are hand weeding, transplanting paddy (in Aurepalle), and cotton picking (in Kanzara). Men engage mainly in activities involving animal draught power: ploughing, harrowing, and interculturing, *i.e.*, mechanical weed control. Moreover, (male) family members are responsible for the general management and supervision of crop production.

2.4.1. Labour market

Village labour markets were reasonably competitive and responsive to the forces of supply and demand. Linkages with the markets for land and credit were the exception rather than the rule. The bulk of labour income was earned in the daily-rated labour market (see Table 2.4). This market was impersonal in nature: employers were usually indifferent to the caste or socio-economic status of prospective day workers, and workers were willing to work for almost all employers.

Table 2.4. Composition and variability of wage income (1979-1984)

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
casual farm wages	0.65	0.85	0.21	0.53	0.80	0.34
	(0.50)[a]	(0.53)	(2.35)	(0.46)	(0.73)	(2.00)
casual nonfarm wages	0.16	0.10	0.40	0.15	0.04	0.12
	(1.55)	(1.70)	(0.99)	(1.30)	(1.81)	(1.74)
regular wages	0.19	0.05	0.39	0.28	0.11	0.42
	(1.14)	(1.20)	(1.43)	(0.48)	(2.45)	(0.57)

Note: [a] median inter-household coefficient of variation for the level of income in parentheses.

Most farm households were both buyers and sellers of labour (see Table 2.5). During the survey period, hired labour provided as much as 60 to 80% of total labour use in crop production. Of total female labour used in the villages, as much as 80 to 90% was hired. The resulting employment provided the lion's share of wage employment.

As labour was geographically immobile, village labour markets were insular. Within a village, wages were mostly uniform for a given operation, season, and sex. An all-India study shows that wages were higher in villages where nonfarm work opportunities are relatively plentiful (Mazumdar, 1989). There was some unemployment in both villages, but the problem was greatest in Aurepalle in the dry season. In Kanzara, employment was relatively secure due to the favourable production environment and, since 1979, the presence of a public-works programme.

Table 2.5. Percentage of farmers hiring and selling labour (1975-1984)

	Aurepalle		Kanzara	
	% selling labour	% hiring labour	% selling labour	% hiring labour
small farmers	89	88	98	100
medium farmers	77	96	97	100
large farmers	12	99	63	100

2.4.2. Credit market

The study villages had a reasonably well-endowed credit infrastructure: there was a credit co-operative in each village and a bank at less than 10 kms distance. Formal financial institutions resulted from a supply-leading approach to agricultural credit, which is rooted in the overriding concern for increasing agricultural production and for diminishing farmers' oppressive debt to informal sources, particularly moneylenders. Because of this policy, moneylenders lost ground relative to institutions over the period 1951-1981 (Bell, 1990). Formal credit, mainly from the credit co-operative, had replaced most informal loans in Kanzara. On the other hand, a well-developed traditional money-lending system still existed in Aurepalle, where misappropriation of funds or wanton borrower delinquency had limited the historical impact of the village credit co-operatives. Moreover, farmers in this drought-prone village highly appreciated the flexibility of informal loans compared to the very strict terms of the credit co-operatives.

The availability of good credit infrastructure does not necessarily imply that all households had sufficient access to credit. Economic theory predicts that informational asymmetries will cause rationing in the credit market (*e.g.*, Hoff and Stiglitz (1993) and

Stiglitz and Weiss (1981)). Lenders may lack information about borrowers' goals and actions, as well as about the risks of the projects being financed. As the interest rate influences the riskiness of prospective projects, credit is rationed according to other —nonprice— screening mechanisms, such as collateral requirements (Barry *et al.*, 1995). This may imply that certain types of farms are more affected by credit rationing than others. Phimister (1995) suggests that small farms belong to this category. As they have more difficulty in generating funds from savings, they may face a higher demand for external funds relative to their profitability and collateral.

In line with the above reasoning, credit was disproportionately concentrated among the large farmers in the study villages (see Table 2.6). These farmers were more eligible for loans: they had more collateral and fixed costs weigh less heavily on larger loans. Still, one cannot simply attribute low levels of credit use by small farmers to supply constraints. Small farmers may voluntarily abstain from (much) borrowing for several reasons. First, the return on capital may be low (Baydas *et al.*, 1994). Second, banks and co-operatives prescribe fixed loan scales and seasonal repayment discipline, which restrain the flexibility needed by the farmer. Third, farmers may not be willing to take a loan because this loan has to be repaid even after a yield loss. Finally, prudent households choose to maintain the possibility to borrow in the future, when money may be needed even more (Deaton, 1997).

Table 2.6. Credit use by farm households in the study villages (1975-1984)

	Aurepalle			Kanzara		
Landholding class	% credit	Loan size	# loans	% credit	loan size	# loans
Landless	5	416	122	1	56	87
small farmers	12	845	156	10	441	110
medium farmers	28	2095	142	23	716	156
large farmers	55	3804	158	66	2065	155
Total	100	1870	578	100	905	508

Source: Maitra, 1996.

Empirical evidence confirms the existence of constraints on long-term borrowing. Binding credit constraints limited investment in irrigation (Pender, 1992a). Moreover, the survey households had limited possibilities to use credit for consumption smoothing from year to year; measured discount rates were significantly higher than the highest interest rate paid by respondents in two study villages in India's SAT (Pender, 1992b). While borrowing did not significantly increase in low-income years in Kanzara, about 75 percent of the income-shortfall households were net borrowers in Aurepalle. Borrowing did, however, not compensate the large income risks in the latter village: the variability of consumption was higher in high-risk Aurepalle than in relatively rainfall-assured Kanzara. What is more, households in both villages appeared unable to offset fluctuations in crop returns through changes in assets and liabilities (Ravallion and Chauduri, 1997; Townsend, 1994).

Contrary to the compelling evidence on long-term credit constraints, empirical evidence on the adequacy of short-term production credit is mixed. Most smallholders had some access to short-term formal loans. A study in all three permanent ICRISAT villages shows that between 1975 and 1984 the only farm households systematically excluded from institutional credit were the rare households headed by widows. Studies from other parts of India present a similar picture: *e.g.*, 74% of all households that wanted a formal loan could get one in the economically diverse state of Uttar Pradesh (Kochar, 1997b). Moreover, access to formal or informal credit did not affect land rental decisions in the same state (Kochar, 1997a). According to Kochar, this suggests that lack of access to credit did not constrain households in their working capital requirements. Therefore, he concludes the following: 'The finding ... suggests that credit constraints cannot explain levels of input use.' However, credit constraints may affect input intensity even if they do not influence the size of the cultivated area. All-India district-level data indicate that this may be the case for Indian smallholders: the availability of formal credit, as measured by the availability of credit institutions, was an important determinant of agricultural input use (Binswanger and Khandker, 1993; Binswanger and Khandker, 1995).

2.4.3. Agricultural production risk

As weather variability is a major cause of the strong yield fluctuations in the SAT, one may expect a high covariance of yields within a single village. Yield covariance results not only in covariate crop incomes but also in covariate harvest-labour demand. In years with bad harvests, aggregate labour demand is low. Yields covariance, therefore, limits the extent to which small farmers can use the (mainly agricultural) labour market to hedge crop income, a strategy suggested in Chapter 1.

Contrary to common expectations, most variation in total household income was idiosyncratic (Townsend, 1994). More specifically, there was little co-movement in crop incomes across farm households in either study village: aggregate variables explained only 40% and 33% of variation in a regression of kharif profits in real Rupees in Aurepalle and Kanzara, respectively (Kochar, 1999). This is not exceptional for the SAT: Carter (1997) estimated that village-level variation accounted for less than half of the variance of dryland yields in semi-arid Burkina Faso. Hence, when investigating the impact of risk on the behaviour of SAT farm households, weather will be a very incomplete risk proxy, and household-specific proxies for risk are required.

In Aurepalle, the explanation for the lack of yield covariance lies in the heterogeneity of crops and soils (Townsend, 1994). Moreover, rainfall appears nonuniform even across plots within the village. Because of this heterogeneity, the correlations between yields from different crops were relatively low, ranging from 0.09 to 0.81 (but with large confidence intervals). Likewise, cross-soil correlations were low: *e.g.*, the yield correlation for castor planted in medium to shallow black soils and in shallow red soil was only 0.37 (Townsend, 1994).

Relative to Aurepalle, Kanzara presents a picture of apparent uniformity, with most households planting some cotton intercrop mixture in medium black soils. Rainfall is more abundant and less erratic in amount and timing. Nevertheless, crop diversification significantly decreased the variability of total crop income. Besides, non-rainfall-related sources of risk, like pests and diseases, are relatively important in this village. These sources of risk are mostly idiosyncratic.

Economic theory suggests that, contrary to covariate risk, idiosyncratic risk may not affect household welfare. In a Pareto-efficient allocation of risk within a community, idiosyncratic income shocks are completely insured within the community, and households face only aggregate risk (Bardhan and Udry, 1999). Efficient allocation of risk can be supported by a competitive equilibrium with completely contingent markets. The existence of such a rich set of markets is, however, incredible given the information and enforcement problems associated with insurance contracts. Still, some communities have developed insurance systems that permit the allocation of risk to approach Pareto efficiency. These systems are based on generalised reciprocity. In small communities, where information flows very freely and the social pressure is high, flexible credit transactions may serve as an insurance against idiosyncratic shocks (Udry, 1990). In the study villages, however, a fully Pareto-efficient allocation of risk is not achieved, and some idiosyncratic risk remains uninsured (Ravallion and Chauduri, 1997; Townsend, 1994).

The introduction of formal insurance programmes seems an obvious answer to crop yield risk. Crop insurance for common crops is, however, not an effective means to reduce income variability, as farmers adapt their cropping pattern to emerging information on rainfall events. The alternative, rainfall insurance, would reduce (crop) income risk only marginally, for it is not possible to relate rainfall to crop yield based on some very simple characteristics of the annual rainfall patterns (Bakker, 1992).

2.4.4. Summary of the main characteristics of the study villages

The villages represent different agro-ecological zones of India's SAT (see Table 2.7). Aurepalle represents red soil areas with high rainfall variability, while Kanzara is situated in a relatively rainfall assured region with medium-deep black soils. 10% of the cultivated area was under irrigation in Aurepalle, compared to only 3% in Kanzara. These different growing conditions resulted in a diverging cropping patterns for the two villages. In Kanzara, most farmers grew cotton intercrops, while Aurepalle farmers cultivated a large variety of crops ranging from sorghum to castor and paddy. Both the average productivity of agriculture and the stability of yields were lower in Aurepalle than in Kanzara.

Just like the biophysical environment, market conditions in the two villages differed considerably. The Kanzara labour market was buoyant due to the favourable agricultural production environment and the close proximity of a public-works programme. On the other hand, Aurepalle households faced relatively high unemployment rates during the dry season. Both villages had a credit co-operative. Besides this formal institution, there was an active informal credit market in Aurepalle. This allowed the village households to smooth consumption somewhat from year to year. Nevertheless, the household's capacity to smooth consumption was limited in both villages.

Table 2.7. Summary of the characteristics of the study villages

	Aurepalle	Kanzara
soils	heterogeneous (mostly) red soils	homogeneous medium-deep black soils
rainfall	unassured, 630 mm	assured, 890 mm
irrigation	10%	3%
major crops	sorghum, castor, pearl millet, paddy, pigeon pea, groundnut	cotton, sorghum, mung bean, pigeon pea
risk	high production risk	moderate production risk
labour market	dry season unemployment	buoyant, public-works since 1979
credit market	credit co-operative, active informal market	credit co-operative

2.5. Theoretical framework

2.5.1. The farm household

This study considers the farm household as a complex of three separate economic identities: the farm firm, the worker household, and the consumer household. The farm firm combines inputs to produce agricultural outputs. When necessary, the concept of the farm firm can be extended to include nonagricultural activities. The worker household supplies labour to its own and market production and earns labour income. Finally, the consumer household spends money to maximise utility (Nakajima, 1986). Together, the worker household and the consumer household form the consumption side of the farm household: the household decides on the allocation of its full income (nonlabour income plus the value of the time endowment) to home time and various consumption goods.

The behavioural principle of the household is to maximise utility, which is a positive function of consumption and home time and a negative function of income instability (Newbery and Stiglitz, 1981). The household maximises utility by allocating labour time of family members and capital resources to farm and off-farm activities, subject to budget and time constraints, ownership of land and capital stocks, and crop technology (Otsuka *et al.*, 1992). As the main interest of this study is current crop production, the remainder of this section focuses on farm household decisions during a single agricultural year and ignores intertemporal savings and investment decisions.

Figure 2.2 gives a schematic representation of the household decision process analysed in this study. Reading from left to right, the household allocates its resources to home time and two productive activities: farm production and wage employment. Home time is time not spent in directly productive and labour market activities. It includes family maintenance, family reproduction, socialisation, and leisure. Wage employment requires only family labour, while farm production combines family labour with land and external inputs. These inputs are purchased using their own or borrowed financial assets. Wage employment and farm production both yield income, which is spent on consumption and the repayment of debts.

Agricultural production is risky, and the returns on crop production are uncertain when the farm household must assign most of its resources. In doing so, they will account not only for the relative returns of the different activities and technologies, but also for their riskiness. Depending on their consumptive preferences, different households will assign different weights to expected income and income variability. To be more specific, wealthy households have more means to cope with an incidentally low income than poorer households have. A wealthy farm household can, therefore, take relatively high amounts of risk and will allocate its resources to relatively risky, but profitable, activities (Rosenzweig and Wolpin, 1993).

For the schematic view of the farm household, this implies that the farm firm cannot be considered as a separate unit that maximises profits. The three spheres of the household interact, and the characteristics of the consumption and labour sphere affect production decisions just like the characteristics of the farm (Singh *et al.*, 1986b).

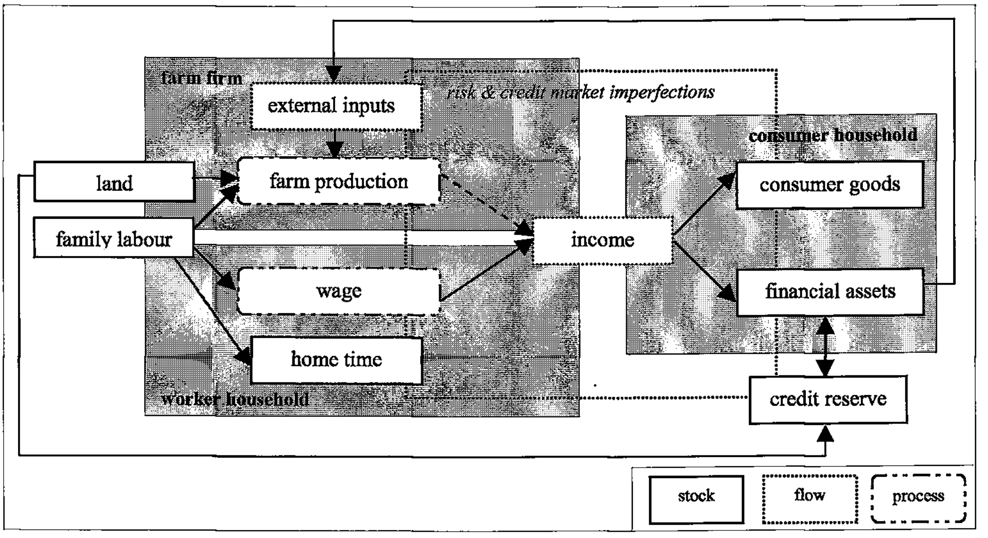


Figure 2.2. The three spheres of the farm household

Credit constraints may be another reason for nonseparability of production and consumption decisions. Farm households cannot borrow indefinite amounts of money. Depending on, for example, its land endowment, each farm household can borrow up to a certain maximum. This maximum and the current liabilities determine how much a household can still borrow: the credit reserve. If the demand for credit is larger than the available credit reserve, the household is capital constrained and their engagement in capital-intensive productive activities is limited.

Risk and credit constraints may cause similar behaviour. Poor households are generally assumed to be both risk-averse and prudent. Prudence implies that households have a precautionary motive for saving, *i.e.*, that they will save more when future income is more uncertain (Browning and Lusardi, 1996). Moreover, prudent consumers may be reluctant to borrow even when loans are available. A loan may protect income now, but it must be repaid in the future. At that moment, income may be even lower (Deaton, 1992b). As most data sets do not indicate whether low levels of credit use are the results of supply or demand limits, distinguishing between the effects of prudence and credit constraints is often impossible.

2.5.2. Estimating farm-household models

Farm household models are designed to capture interactions between the three different spheres of the farm household in a theoretically consistent manner. A basic farm household model consists of a utility function, a production or profit function, and budget and time constraints (Singh *et al.*, 1986b). These functions formalise the decision process described above.

The model is separable if all markets exist, the farm household is a price-taker in each market, and there are no gaps between sales and purchase prices. The household behaves as if production and consumption/work decisions were made sequentially. First, the household solves the production problem. It maximises crop profits subject to input and output prices, resource endowment, and the current level of technology. In order to do so, they demand inputs and supply outputs. Second, the household solves the consumption/work problem. It maximises the utility of home time and consumption given the level of profits achieved in production, wage rates, and consumption prices.

Under separability, econometric estimation of a separable household model can, hence, be divided into two independent parts: the production and consumption systems. The production part covers a standard system of a profit function, output supply functions, and input demand functions. The consumption system consists of a set of demand functions for consumer goods and home time. These systems can be estimated with regular micro-economic approaches to firm or consumer behaviour.

If there are market failures, (some) prices become endogenous, and the separability condition breaks down. Analysis of farm-household behaviour in such a situation requires a household approach which involves simultaneous estimation of production and consumption behaviour. The complete structural system of equation covers equations for consumption and the production behaviour equalling the standard micro-economic equations, but for the endogeneity of prices (Sadoulet and De Janvry, 1995). Estimation of such a complete system is complex and, for that reason, usually not done. The literature presents several approaches for the estimation of the reduced form.

A first approach focuses on the time allocation of farm households under labour market imperfections (*e.g.*, Abdulai and Regmi, 2000; Jacoby, 1993; Mishra and Goodwin, 1997; Newman and Gertler, 1994). In the presence of labour market imperfections, the shadow wage rate of family labour may deviate from the market wage rate. This is the case if the household does not participate in the labour market and there is a price band between hiring and selling labour. A second situation in which the returns on family labour are endogenous is if a household does not sell labour and there are inefficiency differences between hired and family labour. In both cases, the endogenous shadow wage rates equal the marginal returns of family labour in crop production. The latter can be calculated on the basis of the agricultural production function. Substituting the endogenous wage rates in the standard labour supply functions allows a straightforward estimation of farm-household labour supply. Separability of the household model is rejected if the shadow wage rates are significantly different from the market wage rate.

A second approach focuses on the estimation of input demand functions when some inputs are nontradable (Lambert and Magnac (1992), according to Sadoulet and De Janvry (1995)). The household's production decision on inputs corresponds to a cost minimisation problem with endogenous prices. The solution to this problem is a set of demand functions for the tradable inputs. The independent variables in these functions are the exogenous prices, the household resource endowment, the amounts of nontradable inputs used, and the level of output. These functions can be estimated with standard regression methods, provided that one accounts for the endogeneity of the nontradables and the output. Based on the demand functions for tradable inputs, one can calculate the shadow prices of the endogenous inputs.

The most widely followed approach is applicable to all household decisions under all market failures. This approach considers the fully reduced form of the model (Behrman *et al.*, 1997; Iqbal, 1986; Saha, 1994). The endogenous prices are themselves functions of the exogenous prices, resource and time endowments, and household preferences. Substituting these variables for the endogenous prices gives a system of equations with identical independent variables for each equation. There is no justification for any specific functional forms of the system, and any flexible form can be chosen. Moreover, one can estimate the demand for a subset of inputs or home time without having to deal with a full system. Testing for separability of the household model based on this system of reduced form equations is simple: if the parameters of the vector of household time endowments and consumption preferences are jointly significantly different from zero in the input demand equations, separability is rejected (Benjamin, 1992).

Simulation using a complete household model may render interesting information for policy- makers. When the full nonseparable model is not simultaneously estimated, a pragmatic approach involves calibrating the model as though it were separable (De Janvry *et al.*, 1992). This implies assuming that all prices are observed and that credit constraints are not effective at the base point. While this is clearly inconsistent, comparing the solutions with and without market failures at least give a qualitative idea of the importance of these failures to household behaviour.

The fully reduced-form approach was followed in the present study. The advantage of this approach is that it provides consistent estimates of household decisions regarding labour supply as well as input use when the major missing market is the market for risk. The disadvantage is that the reduced form of a household model does not tell us more than that the exogenous variables of the model determine the choices of the farm household. The link between the reduced form and the underlying model is, therefore, weak. Why then, would we bother to specify the exact model? Can we not just take a reduced form equation from the literature? First, a formal model provides a rationale for the relevant exogenous variables to be included in the specific setting of the research. Second, and probably more important, a formal model provides insight into the decision process underlying the reduced form equations. Although it is impossible to derive functional forms from a nonseparable household model, such models often allow prediction of the direction of the impact of various exogenous variables. These can be different for different market constraints. As we shall see in Chapter 4, labour market constraints, for example, will result in a positive impact of family labour on labour used in crop production, while risk can cause the opposite effect. Hence, careful interpretation of the impact of the exogenous variables on household decisions can lead to an understanding of the underlying constraints, provided that an appropriate analytical model is specified.

The problem with all reduced-form estimates is to choose an appropriate functional form. Theory may give us some basic insights — input use functions should demonstrate decreasing marginal returns — it does not dictate the functional relationship between, *e.g.*, household preferences and labour use. The only solution is to let the data speak: select a number of feasible functional forms and determine by testing which fit the data best. Feasibility involves not only known theoretical relationships, but also the use of degrees of freedom. Given the complexity of the relations estimated, the focus in the present study was on linear and loglinear functions.

3. THE SEASONALITY OF LABOUR SUPPLY UNDER RISK:
A Two-Stage Model of Farm Households in India's Semi-Arid Tropics

While previous research has demonstrated that farm households use variations in family labour supply to smooth income, there is little evidence of the impact of the seasonal nature of agricultural production on farmers' labour supply. A two-stage farm-household model was developed that provides insight into the seasonal determinants of labour supply under risk. The empirical analysis uses a novel measure for production risk. This measure mimics the information available to the farmer more closely than the commonly used historical variance. Moreover, the analysis does not require tedious estimation of production shocks. Estimates for two Indian villages confirm the use of family labour for ex ante risk management as well as ex post risk coping. These results have important implications for research on the cost of income uncertainty for farm households, which currently focuses on asset accumulation. Moreover, interventions in labour markets can significantly improve the economic security of farm households.

3.1. Introduction

Labour is the major productive resource for landless and small-farm households in rural India. Employment opportunities are thus important determinants of household income, and seasonal employment fluctuations may have serious effects on household welfare. Consequently, India and other countries such as Pakistan and Bangladesh have adopted public-works programmes to provide employment during the slack season. Both the design and prior evaluation of the effects of such programmes on rural incomes require an understanding of the seasonal determinants of labour supply and demand decisions of farm households.

Skoufias (1993) shows how seasonal modulations in the agricultural cycle affect labour-demand decisions of Indian farm households. He concludes that ignoring the timing of application of labour inputs has a significant impact on the estimated response of labour demand to exogenous changes in, for instance, wages. The same holds for ignoring heterogeneity arising from differences in risk preferences. Similarly, we can expect that risk and seasonality will affect rural labour supply.

The seasonal reactions of farmers' labour supply to production risk are not only important because of their impact on employment and wage income. Previous research shows that consumption is smoother than income in rural India (Townsend, 1994). As formal insurance markets are absent and consumption credit is scarce, it is widely believed that consumption smoothing is achieved through asset transactions. The cost of this strategy is high; due to both *ex ante* portfolio choices that favour more liquid but less productive assets and to the *ex post* sale of assets at a loss (Eswaran and Kotwal, 1989). Flexible labour markets may decrease income fluctuations and, thus, the need for such costly transactions.

Ideally, farm households can use labour markets for both *ex ante* risk management and *ex post* risk coping. On the one hand, they can work long hours early in the cropping stage and assure a certain wage income when crop income is still erratic. On the other hand, they can decide to work extra hours when crop income turns out to be low. Evidence on the feasibility of these strategies may have strong implications for models of savings and investment that claim that a significant share of the savings of farm households in developing countries represents a precautionary response to uncertain crop incomes (Deaton, 1989).

Most labour supply studies do not explicitly account for risk and seasonality. Woldehanna (2000), *e.g.*, presents an elaborate nonseparable farm-household model including labour supply to farm work, off-farm work, leisure, supervising hired farm labour, and transacting the off-farm labour market. The household faces numerous market imperfections: a cash constraint, an entry barrier in the labour market, transaction costs in off-farm work, and input purchase. However, the model is deterministic and covers a single period only: the agricultural year.

A number of recent studies touch upon risk and seasonality, but none provides an empirically tractable method for estimating the impact of both *ex ante* and *ex post* risk behaviour as described above. Kanwar (1991) concentrates on *ex ante* risk management, while Kochar (1995; 1999) covers *ex post* risk coping. Both estimate all year market labour supply and do not distinguish between different seasons. Moreover, Kochar doubts the reliability of his results because of data limitations: his concept of a yield shock is difficult to apply empirically. Fafchamps (1993) models labour supply under risk in three stages of the cropping season. His model is, however, not suitable for studying the issues mentioned above, as it does not consider labour market transactions. Inspired by the Indian context, Skoufias (1994) developed a two-stage model of labour supply under well-functioning labour markets. He models the household's possibility to increase labour supply in anticipation of a possible income shock as well as in reaction to a realised yield shock. The empirical model is formulated such that all risk factors are incorporated in the individual effects, which disappear from the equations after taking first differences. This method is only consistent under perfect lifetime credit markets, an assumption that has been rejected in the Indian context (Binswanger and Khandker, 1993; 1995; Pender, 1992). Even Skouffias' himself concludes in his thesis underlying further publications that: 'Accounting for credit constraints at the empirical level is very important to the farm modelling approach and should be pursued further' (Skoufias, 1988). As soon as the assumption of perfect lifetime credit markets is released, Skoufias' reduced form equations and estimation method are no longer valid. The alternative reduced form equations for labour supply explicitly include risk.

The contribution of this chapter to the literature is twofold. First, it presents a farm-household model that shows the impact of risk on labour supply in the absence of long-term credit markets and under different assumptions regarding short-term credit markets. The outcomes of the model are tested empirically for two villages in India's semi-arid tropics (SAT). Estimation of *ex post* behaviour does not require estimation of income shocks: information about actual income is sufficient. Second, this chapter introduces a risk measure derived from the production literature in a study on farm-household behaviour. Past studies used time series of income or production to estimate risk (*e.g.,* Saha, 1994, Kanwar, 1991). These measures do not accurately measure risk as perceived by the farm household, which has more than just historical information. The Just-Pope variance from the production literature includes as much of this information as possible.

The structure of the chapter is as follows. Section 3.2 describes the analytical model used for the analysis of labour supply under risk and credit constraints. Section 3.3 discusses the empirical issues involved in the estimation of yield risk and presents estimates for the two study villages. Section 3.4 presents the labour supply estimates. Conclusions are presented in Section 3.5.

3.2. Modelling framework

In order to show the impact of risk on farm-household labour supply, a two-stage farm-household model was developed. The model is similar to that of Skoufias (1994) in that it assumes perfect labour markets and models two agricultural stages with stochastic production in the first stage and deterministic production in the second stage. The main difference between the two models lies in the assumptions regarding the functioning of credit markets and the household time horizon.

Skouffias assumes that the household maximises lifetime utility under perfect credit markets. This approach leads to a convenient set of equations for household labour supply and demand. Labour supply is a function of the production stage, the wage rate, household preferences, and the utility costs of giving up one unit of consumption. Similarly, labour demand is a function of the production stage, the endowment of fixed production factors, the prices of inputs and outputs, and the utility costs of giving up one unit of consumption. The utility variable figures in both the labour supply and demand equations and thus reflects the nonseparability of the model. Skoufias assumes that the utility variable is constant over time. Consequently, it disappears when computing first differences in a panel data set. In other words, when using fixed effects estimation, labour supply and demand can be estimated as if the model were separable. This is computationally very convenient, but is conditional upon the assumption of perfect credit markets over the household's lifetime.

Empirical research strongly rejects the latter assumption for the study area. There is very limited long-term credit (Walker and Ryan, 1990) and consumption smoothing from year to year is limited (Ravallion and Chauduri, 1997; Townsend, 1994). As a result, measured intertemporal discount rates exceed actual interest rates (Pender, 1992b). Skouffias (1994) acknowledges that credit market imperfections are likely to affect the estimates of labour supply. He states that further research on this issue should be pursued.

The current model assumes a time horizon of a single agricultural year only and hence a total absence of long-term credit (*i.e.* credit between years). Pender (1992a) used the assumption of no long-term credit in his model of irreversible investment in India's SAT. Moreover, Saha (1994) and Kanwar (1991) used single-year models for analysing farm-household labour supply in India's SAT. The current model covers a single year for two reasons. First, the research questions concern household decisions that are made within a single agricultural year. A single-year model gives the clearest representation of these decisions. Lifetime models can be relatively simple, but only if it is assumed that credit markets are perfect over the entire period. As described above, this is an unrealistic assumption in the study area. Second, previous research indicates that the impact of long-term considerations on short-term decisions is small. Previous research on farmer's labour supply shows that non-current wage rates play a minor role in labour supply (Skoufias, 1996). Moreover, limited access to long-term credit markets results in myopic behaviour of asset-poor households (Deaton, 1989).

The approach to short-term credit is more ambiguous than that to long-term credit. As indicated in section 2.4.2, previous research has not given a conclusive answer as to whether farm households have sufficient access to short-term credit to finance inputs and the desired pre-harvest consumption. Hence, the current model allows households to borrow in the planting stage, conditional on repayment in the harvest stage. However, households can only borrow up to a certain amount. Whether this amount is limiting is essentially an empirical question.

3.2.1. The two-stage model

The model starts from a two-stage whole farm production function. In the planting stage (denoted by subscript 1), the household allocates labour (L_1) to plant and grow a crop on a given acreage[3]. At this moment, there is uncertainty about exogenous factors influencing crop production (ε), such as weather and pest infestation. The impact of these factors on crop production depends on the labour input and the inherent riskiness of the household's land (γ), which is the result of the local weather, the terrain, and soil characteristics (Just and Pope, 1979):

$$Q_1 = f(L_1) + h(L_1)\gamma\varepsilon, \quad \varepsilon \sim N(0,1). \tag{3.1}$$

This function includes two related measures for risk: the inherent riskiness of the household's land (γ) and the riskiness of the land use system ($h\gamma$), which is the result of the interaction between the inherent riskiness of land and the household's production decisions. This distinction is useful as the household faces risk that is exogenous to its behaviour (the inherent risk), but can at least partly affect the actual risk of its activities (the riskiness of the land use system) through its behavioural choices.

Eq (3.1) is formulated such that $E(Q_1)=f(L_1)$ and $Var(Q_1)=h^2(L_1)\gamma^2$. In this way, the effects of inputs on the mean and variance of output can be independent.[4] f_{L1} (the marginal product labour) is always positive, while $h_{L1}\gamma$(the marginal risk effect of labour) can be either positive or negative. Both positive and negative relations are found in Philippine rice production, depending on the activity and technology at hand (Antle and Crissman, 1990).

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[3] Labour is the main variable input in the study area. Other frequently used inputs are bullock traction and inorganic fertilisers. For the sake of transparency, these inputs are not included in the analytical model. Alternatively, one could replace L_1 by V, a vector of variable inputs.

[4] Gautam (1993) tested for the significance of skewness in the production process for food crops, cash crops, and irrigated crops in Aurepalle. The results of these tests do not obtain significance. Besides, Walker and Ryan (1990) conclude that most improved cropping systems and traditional intercrops are characterised by normal yield distributions in the two study villages. Hence, I believe that the assumption of normality is justified. Alternatively, representation of risk by the standard deviation can be justified by assuming that a second-order Taylor's series expansion of the yield distribution is sufficient to capture the relevant risk characteristics.

The output of the planting stage is the standing crop (Q_1), which the farmer observes in the beginning of the harvest stage (denoted by subscript 2). In this stage, all uncertainties regarding production are resolved and the farmer harvests the crop (Q_2) using labour (L_2):

$$Q_2 = g(Q_1, L_2). \tag{3.2}$$

Note, unlike in static models, output and production costs are not all contemporaneous: part of the labour costs is borne in the planting stage, while all output is realised in the harvest stage.

The household can generate income through wage employment as weel as through crop production. Labour can be hired in and out freely at a single wage rate (w). While the availability of long-term credit is limited in India's SAT, an extensive network of co-operatives and informal lenders provide short-term production credit. The model, therefore, allows for borrowing in the planting stage (B). All loans must be repaid at harvesting at interest rate r, and there is a maximum to the amount that a household can borrow (B_m). The size of this amount depends on the characteristics of the household (Z). The household consumes (C) in both stages, and at the end of the harvest-stage, all income is consumed. Hence, the budget constraints are

$$C_1 = w_1(F_1 - L_1) + B, \tag{3.3}$$
$$C_2 = pg(f(L_1) + h(L_1)\gamma\varepsilon, L_2) + w_2(F_2 - L_2) - (1+r)B, \tag{3.4}$$
$$B \leq B_m(Z), \tag{3.5}$$

where p denotes the output price. L is the sum of family and hired labour in farm production, while F is the household's total labour supply, *i.e.*, the sum of on-farm and off-farm family labour.

The difference between each period's total time endowment (T) and family labour supply (F) equals home time (ℓ):

$$\ell_t = T_t - F_t \quad t = 1,2. \tag{3.6}$$

The household facing these constraints maximises the utility (U) of consumption (C) and home time (ℓ) in both stages. Households are risk-averse and prudent, and the precise form of the utility function depends on the household's characteristics (Z). The household decision variables are family labour supply (F) and labour use (L) in both stages, and borrowing (B) in the planting stage.

The above implies that the harvest-stage decision problem is

$$W = \underset{L_2, F_2}{Max}\, U(C_2, \ell_2; Z) \quad U_i > 0; U_{ii} < 0; U_{iii} > 0; \quad i = C, \ell, \tag{3.7}$$

subject to:

$$C_2 = pg(Q_1^*, L_2) + w_2(F_2 - L_2) - (1+r)B^*, \tag{3.8}$$

$$\ell_2 = T_2 - F_2, \tag{3.9}$$

where * implies that a variable is predetermined: B^* is a planting-stage decision variable and Q_1^* is the result of the planting-stage decision regarding L_1 and the outcome of the stochastic shock ε. p, T_2, w_2 and r are given.

The following equation combines the two constraints:

$$C_2 + w_2\ell_2 = pg(Q_1^*, L_2) - w_2L_2 - (1+r)B^* + w_2T_2. \tag{3.10a}$$

Hence, the household equates the total value of consumption and home time to the sum of crop profits and the value of family labour minus loan repayment, *i.e.* full income (Y):

$$C_2 + w_2\ell_2 = Y. \tag{3.10b}$$

The use of this notation will become clear below.

Substituting Eqs (3.8) and (3.9) into Eq (3.7.) gives

$$W = \underset{L_2, F_2}{Max}\, U\left(pg(Q_1^*, L_2) + w_2(F_2 - L_2) - (1+r)B^*, T_2 - F_2; Z\right). \tag{3.11}$$

Recall that the harvest-stage decision variables are labour supply (F_2) and labour use (L_2). The respective first-order conditions are

$$g_{L_2} = \frac{w_2}{p}, \tag{3.12}$$

$$U_{\ell_2} = w_2 U_{C_2}. \tag{3.13}$$

This is the standard result for farm-household models assuming perfect markets (Singh *et al.*, 1986b). Harvest-stage production and consumption decisions are separable. First, the household maximises profit by setting the value of marginal product of labour equal to the wage rate (Eq (3.12)). In other words, the household chooses the amount of harvest labour, given the output from the planting stage, the harvest wage rate, and the output price. When the profit maximisation choices are made, the household knows its full income (Y, see Eq (3.10)). Subsequently, the household maximises utility by setting labour supply such that the marginal utility of consumption equals the value of the marginal utility of home time (Eq (3.13)). This implies that they optimise the ratio of consumption and leisure, given harvest-stage full income, the household time endowment, the harvest-stage wage rate, and household preferences. Consequently, the reduced form equations for harvest labour supply and labour use are

$$L_2 = L_2\left(Q_1^*, p, w_2\right), \tag{3.14}$$

$$F_2 = F_2\left(T_2, w_2, Y^*, Z\right), \tag{3.15}$$

where * again indicates that the variable is predetermined: Q_1^* is an outcome of the planting-stage production process, while Y^* is an outcome of planting-stage borrowing B^* and harvest-stage profit maximisation given Q_1^*.

Hence, the planting-stage decision problem is

$$V = \underset{L_1, F_1, B}{Max}\left(U(C_1, \ell_1; Z) + \rho EW\left(Q_1^*, B^*\right)\right) \quad U_i > 0; U_{ii} < 0; U_{iii} > 0; \quad i = C, \ell, \tag{3.17}$$

subject to:

$$C_1 = w_1(F_1 - L_1) + B, \tag{3.18}$$

$$B \leq B_m(Z), \tag{3.19}$$

$$\ell_1 = T_1 - F_1, \tag{3.20}$$

where ρ is the intertemporal discount factor, and E denotes expectation.

The Lagrangian for this problem is

$$\begin{aligned}\Im = U[w_1(F_1 - L_1) + B, T_1 - F_1] + \rho EU[pg(f(L_1) + h(L_1)\gamma\varepsilon, L_2) \\ + w_2(F_2 - L_2) - (1+r)B, T_2 - F_2; Z] + \lambda(B_m - B)\end{aligned}, \tag{3.21}$$

which we get by inserting Eqs (3.18), (3.20), (3.11), and (3.1) into Eq (3.17). Moreover, the Lagrangian multiplier λ accounts for the borrowing constraint (Eq (3.19)).

The three decision variables are L_1, B, and F_1. Note that the choice of L_1 and B affects harvest-stage decisions regarding L_2 and F_2. Moreover, the stochastic shock (ε) affects Q_1 and, thus, L_2 and F_2. Hence, Q_1, L_2, and F_2 are uncertain in the planting stage. We can now derive the planting-stage Kuhn-Tucker conditions (see Appendix 1):

$$f_{L_1} = \frac{w_1}{p}\frac{U_{C_1}}{\rho E(U_{C_2} g_{Q_1})} - h_{L_1}\gamma \frac{E(U_{C_2} g_{Q_1}\varepsilon)}{E(U_{C_2} g_{Q_1})}, \tag{3.22}$$

$$U_{\ell_1} = w_1 U_{C_1}, \tag{3.23}$$

$$U_{C_1} = \rho(1+r)EU_{C_2} + \lambda, \tag{3.24}$$

$$\lambda \geq 0, \tag{3.25}$$

$$B \leq B_m(Z), \tag{3.26}$$

where λ>0 if B=B_m. Note the differences between the harvest and planting-stage condition for labour use (Eqs (3.12) and (3.22)).

3.2.2. *Optimal responses for the planting stage*

Unlike harvest-stage decisions, the optimal labour-supply choice is not separable from the optimal labour-use choice in the planting stage. The marginal utility of planting consumption figures in the first-order conditions for planting labour demand (Eq (3.22) as well as planting labour supply (Eq (3.23) and borrowing (Eq (3.24)). Hence, the household does not simply maximise expected profit, but accounts for its consumption preferences in production decisions. Put differently, labour is not applied until the expected marginal value product equals its discounted price corrected for harvesting costs, as it would be in the case of profit maximisation. The difference reflects the riskiness of the land use system combined with household risk aversion. Moreover, if credit constraints are binding, harvest-stage utility is not discounted at the market rate of interest, but at an endogenous household-specific rate.

The nonseparability of household decisions has important implications for household labour supply. Yield risk will affect not only the amount of labour used in production, but also the household's choices regarding consumption and home time. Credit market imperfections will modify the latter effect, as they weaken the link between planting and harvesting utility.

The sign of the risk elasticity of planting-labour supply is ambiguous and depends on the parameterisation of the utility function. Previous research indicates that households want to guarantee a minimum level of income by working long hours during the planting season (Kanwar, 1991). Family labour is in this case used for *ex ante* risk management, and the relation between risk and planting labour supply is positive.

Although it is not an explicit argument in the harvest-stage first-order conditions, the outcome of the stochastic yield shock unambiguously affects harvest-labour supply: a negative yield shock increases harvesting labour supply and *vice versa.* If we assume that both consumption and home time are normal goods, households will consume less of both when full income decreases. A harvest loss will, therefore, induce the household to decrease home time, which is equivalent to increasing labour supply. The resulting increase in wage income limits the cutback in the consumption of goods. Hence, the farm household uses labour supply to smooth income *ex post.*

Note that the *ex post* strategy hinges on the model assumption that wage income is risk free, or that at least employment risk and crop risk are largely independent. This may not be the case in India's SAT, where village labour markets are insular and yield risk is at least partly covariate. A village-wide negative yield shock will not only lead to a large increase in market labour supply, but also to a decrease in agricultural labour demand. The result is high unemployment rates in years with low crop income. In this situation, low yields will be associated with a decrease in wage income instead of an increase.

Nevertheless, the model may be a good approximation of the situation in the survey area. More than half of the stochastic shock is idiosyncratic (see section 2.4.3), and the correlation between yearly average planting and harvest wage rates is a high as 0.96 in Aurepalle and 0.93 in Kanzara over the 10-year survey period. Previous research indicates that labour income appears to be important for income stabilisation: most households facing more than one severe income shortage during the study period do not have an able-bodied, healthy family member who can participate in the labour market (Walker and Ryan, 1990). Moreover, Kanwar (1998) could not prove that production risk (defined as the coefficient of variation of crop net revenue) Granger causes employment risk (defined as the product of the probability of finding employment in the local casual labour market and the estimated real wage).[5]

3.3. An empirical risk measure

3.3.1. *Inherent riskiness of land (γ)*

The model specifies planting-stage crop production as a composite production function (Eq (3.1)):

$$Q_1 = f(L_1) + h(L_1)\gamma\varepsilon, \quad \varepsilon \sim N(0,1),$$

where f depicts mean production and $h\gamma$ the standard deviation of production. The standard deviation is a function of household behaviour (L_1) and the inherent riskiness of the land (γ). The latter is exogenous to the household and is a function of a vector A of land size, land quality and weather. This vector was not included in the model description of section 3.2. It affects not only the inherent riskiness of land, but also mean output:

$$Q_1 = f(L_1, A) + h(L_1)\gamma(A)\varepsilon, \quad \varepsilon \sim N(0,1). \tag{3.27}$$

Similar Just-Pope specifications are commonly used to determine the relation between the use of variable inputs and the variability of output (Rosegrant and Roumasset, 1985; Smale, 1998; Traxler, 1995). If we assume Cobb-Douglas function forms for all three partial functions, we get

$$Q_1 = \alpha_0 L_1^{\alpha_1} \prod_{k=1}^{K} A_k^{\alpha_{1+k}} + \beta_0 L_1^{\beta_1} \prod_{k=1}^{K} A_k^{\beta_{1+k}} \varepsilon, \quad \varepsilon \sim N(0,1), \tag{3.28}$$

where the α's are the coefficients for the average production function (f) and the β's the coefficients for the standard deviation function ($h\gamma$). The above specification imposes decreasing marginal returns on inputs, allows both positive and negative relations between input use and output variability, and is computationally convenient.

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[5] The series x_t fails to Granger cause y_t if in a regression of y_t on lagged y's and lagged x's, the coefficients of the latter are zero. This means that x does not cause y in the Granger sense if it does not precede y.

Just and Pope (1979, see Appendix 2) developed a three-step estimation method for estimating a composite Cobb-Douglas function like Eq (3.28). However, this method can be applied here only if we assume that planting-stage production equals total production. The composite production function in the analytical model describes planting production, while data are available only on total production. We can get the model's total production function by inserting the planting-stage function (Eq(3.1)) in the harvest-stage function (Eq (3.2)). However, the resulting function is too complex to be estimated. Hence, only if we assume that total production equals planting-stage production can we estimate the total production function. This assumption is probably not very unrealistic. Harvest costs are low relative to the value of the crop to be harvested. Although there might be some impact of the wage rate on the amount of harvest labour used, labour use will be dominated by technical needs. In other words: the farmer simply harvests the given crop. Consequently, the composite production function is estimated as if it describes total crop production.

The first step of the Just-Pope procedure involves nonlinear estimation of the mean production function

$$Q_1 = \alpha_0 L_1^{\alpha_1} \prod_{k=1}^{K} A_k^{\alpha_{1+k}} + \varepsilon^* . \qquad (3.29)$$

This step provides a consistent but inefficient estimate of mean output. The (heteroscedastic) residuals of this regression ($\hat{e}^*$) are estimates of the standard deviation function ($h\gamma\varepsilon$).

The second step yields the information needed to calculate estimates for γ. This step involves estimation of the square of this standard-deviation function: the variance function. Using ordinary least-squares regression (OLS), we can estimate the logarithm of the variance function:

$$\ln\left(\hat{e}^{*2}\right) = \beta_0^* + \beta_1 \ln(L_1) + \sum_{k=1}^{K} \beta_{1+k} \ln(A_k) + u , \qquad (3.30)$$

where u is a random error term with mean 1.2704 (Just and Pope, 1978). Hence, $\beta_0^* = \beta_0 -$ 1.2704. The inherent riskiness of land (γ) can now be computed as follows:

$$\hat{\gamma} = \left(\hat{\beta}_0^* + 1.2704\right) \prod_{k=1}^{K} A^{\hat{\beta}_{1+k}} , \qquad (3.31)$$

where ^ indicates that the parameters and γ are estimated. For the ICRISAT data, the spread of γ appeared insensitive to the precise variables included in A: γs estimated for different vectors A are highly correlated.[6]

The third step of the Just-Pope estimation procedure involves re-estimation of the mean production function (Eq(3.29)) using the predicted standard deviations from stage 2 ($h\gamma$) as weights in a weighted nonlinear least-squares regression (WNLS). The results of step two and three are consistent and efficient for cross-sectional data. Moreover, the three-step procedure yields consistent estimators when panel data are used. The results are theoretically not efficient for panel data. However, using data on American farmers, Griffiths and Anderson (1982) conclude that correction for individual or time effects adds little to the estimation procedure.

The Just-Pope approach to risk differs from the general treatment of production risk in empirical farm-household studies. Previous studies have used historical variance as a proxy for production risk (*e.g.,* Saha, 1994, Kanwar, 1991). This measure has two drawbacks compared to the Just-Pope method. First, historical variance does not just measure exogenous risk, but also past input choices of the household: as we have seen before, the level of inputs used affect output variability. Second, historical variance covers very little if the information available to the farm household. Farmers can observe current weather, which is related to the weather later in the growing season. Besides, the farmers know the current acreage. Owing to fallowing and leasing, this acreage is not constant over the years. Hence, historical variance overestimates the actual risk that the farm household faces. What is more important, there is no reason why the deviation between historical variance and real risk would be equal for all farmers.

3.3.2. The production function

Separate production functions were estimated for the two villages as general soil and weather conditions are very different. The actual regressions consider not just labour inputs, but also the input of animal traction and inorganic fertilisers. Moreover, two categories of labour were considered: male and female labour. Farmers consider these types of labour as separate inputs, since all pre-harvest activities are gender-specific. The set of land and weather variables covers size of cultivated area, share of irrigation, land value, share of shallow soil, and the share of area under pigeon pea (both villages), local pearl millet (Aurepalle), and

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[6] Even the choice of the set of variable inputs included hardly affects the spread of γ.

local cotton (Kanzara). The crop shares serve as proxies for the farmer's weather information. These crops are commonly cultivated and their adoption is known to be sensitive to expectations of weather. Moreover, the crops are planted early enough so that the area under the crop does not reflect any *ex post* adjustments to weather outcomes (Kochar, 1999). In the Kanzara equations, I added proxies for the household managerial capacity: literacy and the age of the household head. These variables were not included in the Aurepalle equations, as they caused multicollinearity problems. Finally, time trends reflect technological change.[7]

Table 3.1. reports the results for the production regressions. For both villages, the set of regressors significantly explains the mean and variance of production, indicating that these are not randomly distributed around a mean value. Homoscedasticity was rejected at the 10% level in the first-stage regression, indicating that the three-step procedure is superior to the single-step estimation of a conventional loglinearised Cobb-Douglas function. Crop production is measured in monetary units (Rs), as the farmers grew a large variety of crops. The regressions consider kharif production only, which covered over 90% of the cultivated area in both villages. The Aurepalle function for mean production includes a dummy for small farmers. Without this dummy, the mean production function largely overestimates production for all farmers cultivating less than 1.9 hectares. The dummy did not affect output variance.

Contrary to expectations, the estimates predict the variation of production around its mean (almost) equally well for risk-prone Aurepalle as for rainfall-assured Kanzara. Aurepalle farmers were apparently able to smooth production through crop choice and other management measures. The relatively large share of irrigated area in Aurepalle may also explain the high explanatory power of the mean function in this high-risk village. The higher production potential in Kanzara resulted in higher standard deviations of production. The coefficients of variation of output were, nevertheless, higher for Aurepalle.

Mean output was higher for larger plots with a higher land value. The trend coefficients indicate that technological progress has been significant only in Kanzara. Irrigation significantly increased output in Aurepalle, but not in Kanzara. There was very little irrigation in the latter village, rainfall being relatively abundant and assured. The proxies for weather expectations significantly affected only mean output in Kanzara. The absence of a significant effect in Aurepalle may be due to the incompleteness of the proxies or the

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[7] Conform convention, dummies, ratio and the time trend are included in the production function in exponential form: $Y = \alpha_0 X^{\alpha_1} e^{\alpha_2 D}$, where X is a regular continuous variable and D is a dummy, ratio

limited capacity of farmers to predict weather in this high-risk village. In Kanzara, education and age increased managerial capacity and thus yields.

Table 3.1. Three-stage estimates for crop production (Rs[a]) (1975-1984)

	Stage 2: variance OLS, Eq (3.30)		Stage 3: mean WNLS, Eq (3.29)	
	Aurepalle	Kanzara	Aurepalle	Kanzara
Variable inputs				
male labour (hrs)	-0.02353	-0.00632	-0.01519	0.10550*
	(0.20505)	(0.33859)	(0.02332)	(0.05474)
female labour (hrs)	0.08503	0.33515*	0.17504***	-0.08236**
	(0.20288)	(0.20029)	(0.04702)	(0.03754)
inorganic nitrogen (g)	0.06830*	0.08085***	0.02562**	0.03936***
	(0.03845)	(0.02862)	(0.01010)	(0.00872)
bullock labour (hrs)	0.74531**	0.00733	-0.04507	0.36349***
	(0.32013)	(0.39861)	(0.06173)	(0.07383)
Fixed inputs & 'nature'				
cultivated area (ha)	0.71062**	0.73089**	0.63276***	0.40779***
	(0.32976)	(0.38597)	(0.07741)	(0.07595)
land value (Rs/ha)	0.93642**	0.74237**	0.57964***	0.45220***
	(0.46128)	(0.32694)	(0.09426)	(0.06949)
share of irrigated area	-0.25570	1.13613	0.48551**	-0.11528
	(1.23334)	(1.22404)	(0.17016)	(0.16822)
share of shallow soil	0.33905	0.45375	0.09440	0.41168***
	(0.46379)	(0.50121)	(0.07916)	(0.14109)
millet share	0.65356		-0.19391	-0.63458***
	(1.14064)		(0.30925)	(0.13639)
cotton share		0.49601		-0.63458***
		(0.58216)		(0.13639)
pigeon pea share	-0.71368	0.62064	-0.19084	0.62832*
	(1.05848)	(1.92630)	(0.19933)	(0.33895)
dummy area<1.9 ha			-29.4238	
			(30.5030)	
year	-0.03987	-0.13036**	-0.00325	0.02808***
	(0.05891)	(0.05102)	(0.01196)	(0.00938)
Farmer's capability				
literacy (yes=1)		0.33734		0.29803***
		(0.29592)		(0.08398)
age (year)		1.47395**		0.87375***
		(0.64612)		(0.11463)
constant	6.58296	11.7249***	105.969	0.16281
	(4.50381)	(4.38885)	(94.5936)	(0.15055)
Adjusted R^2	0.53	0.42	0.88	0.92

Notes: [a] The value of output is specified in 1983 prices.
Standard errors are in parentheses.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

or trend.

Most input coefficients in the mean production function are significant and have the expected positive sign. Nevertheless, the regressions do not demonstrate a significantly positive effect of the closely related inputs male labour and bullock traction in Aurepalle. The diverse traction requirements of the heterogeneous soils in this village probably obscured the effects of these inputs on mean crop production. In the Kanzara equation, the coefficients for bullock and male labour are both significantly positive. The elasticity for inorganic nitrogen was low in both villages. This could point to a low efficiency of fertiliser use due to limited knowledge about this modern input. The elasticity for female labour was positive and reasonably high in Aurepalle, where large amounts of female labour were used in the highly productive cultivation of paddy. In Kanzara, the most important female task was weeding. The link between weeding and crop production is indirect, as weeding requirements depend very strongly on exogenous variables that may differ greatly between plots. Hence, the estimate for the female labour elasticity is negative for Kanzara.

Output variability increased not only with the size of cultivated area, but also with the value (or quality) of the land. The high potential of good land was apparently mostly realised in good years. Surprisingly, Kanzara's technological progress has lead to a decrease in the variability of output. Irrigation did not significantly decrease output variability in either village, although the coefficient for irrigation is negative in the Aurepalle equation.

Farmers could significantly affect the variability of crop output through the choice of inputs. Nitrogen fertilisers increased output variability in both villages. In addition, output variability increased through bullock traction in Aurepalle and through female labour in Kanzara. The other input coefficients are not significant. The Cobb-Douglas production function may be too restrictive to capture the subtleties of the production process. The data set is, however, too small to allow estimation of a less restrictive composite production function, like the translog. Even using the Cobb-Douglas for, the relatively large variance of the estimates may be due to the complexity of the two-step regression method and the limited sample size. The presence of individual effects may also lead to inefficiency of the estimates. Correction of these effects had little impact on the outcome of the regressions in previous research, but this may not be the case for all data sets (Griffiths and Anderson, 1982). If we ignore the significance level, all input coefficients are positive except for the coefficient for male labour in Aurepalle. This could indicate that all but the latter input increase risk. Nevertheless, the insignificant input coefficients are very small.

Farmers' perceptions of the relation between input use and output variance may not coincide with observed relations. Srimaratnam *et al.* (1987) compared Texas farmers' subjective beliefs with experimental data on grain sorghum yields to different levels of nitrogen fertilisers. Although experiments indicated that nitrogen increased the variance of output at all levels, the variance effect of fertiliser elicited by farmers was negative up to a fertiliser dose of 101 pounds per ha. This indicates that the farmers in Srimaratnam's sample falsely perceived nitrogen as risk reducing, while in fact it was a risk-increasing input. The farmers in the study villages may have had similar misperceptions.

3.4. Farm-household labour supply

3.4.1. The labour supply functions

The model presents the following reduced form equation for harvest-stage labour supply (Eq (3.15)):

$$F_2 = F_2\left(T_2, w_2, Y^*, Z\right),$$

where full income (Y^*) is defined as the sum of harvest-stage crop profits and the value of the harvest family labour endowment minus loan repayment, or equivalently as the sum of total crop profits plus the value of the harvest labour endowment minus planting consumption. In reality, harvest-stage full income includes year-round income from all sources plus the value of the harvest time endowment minus planting consumption. Hence, we need to know only actual full income and not the income shock, *i.e.*, the difference between expected and actual income. Previous research uses this shock to test for the use of family labour for *ex post* income smoothing. The shock is, however, difficult to estimate, which hinders the test (Kochar, 1999). The only problem in determining harvest-stage full income is determining C_1. This study ignores that factor and calculates full income based on total income. This simplification will presumably have little effect on the results, as planting season consumption is a function of expected total income and is necessarily independent of the exogenous shock.

There are two possible regimes in the planting stage: the household is credit constrained or it is not. Both have a different reduced form equation:

$$F_1 = F_1\left(Z, \rho, A, w_1, w_2, p, T_1, T_2, \gamma\right), \qquad (3.32a)$$

$$F_1 = F_1\left(Z, \rho, A, w_1, w_2, r, p, T_1, T_2, \gamma\right), \qquad (3.32b)$$

where Eq (3.32a) holds for the constrained household and Eq (3.32b) for the unconstrained household. The difference between the two equations is the interest rate (r), which affects the planting-labour supply decision of unconstrained households alone. Recall that γ is the inherent riskiness of the land as estimated in section 3.3.1, and is, therefore, exogenous to the equations.

We do not know *a priori* in which regime the sample households were, and different households may face different regimes. Besides, households owning large stocks of liquid assets may use these holdings to smooth consumption and, hence, may not feel the need to vary labour supply in response to risk. Endogenous switching regression techniques are designed to estimate models with more than one latent structure, but are hard to apply with a limited set of panel data, especially if there are three possible regimes. This study, therefore, used a different approach and tested for structural breaks at different levels of land ownership, the main determinant of access to credit, and liquid asset holdings. A structural break was found at an average level of asset holdings of at least 72% of average household income: F-tests reject equality of the coefficients for full income between farmers holding less and more liquid assets at the 1% level. This liquid asset ceiling coincides with a maximum landownership of 8 hectares. As land ownership was exogenous to household behaviour over the time period considered, the largest farm households can be excluded without having to correct for sample selection. For Aurepalle, no threshold was found.[8]

The set of household characteristics (Z) is specified such that it covers proxies for the household's risk aversion and their access to credit and alternative sources of liquidity. Included are the value of liquid assets,[9] the size of area owned, and the value of livestock. Liquid assets and livestock income are alternatives to credit, while land ownership serves as collateral. Moreover, asset endowments serve as proxies for risk aversion: wealthier households have more possibilities to smooth consumption from year to year. These smoothing options are more important for risk behaviour than pure risk preferences. In most developing-country farming communities, villagers hold rather similar preferences regarding risk, and there is no relationship between pure risk aversion and the net household wealth (Binswanger and Sillers, 1983). This was not different for the villages analysed in this study (Binswanger, 1981). However, even if individuals have identical risk preferences, those with

[8] In contrast to households in Kanzara, Aurepalle households are known to increase borrowing in low-income years. In addition to landownership thresholds, I therefore experimented with thresholds related to both levels of liquid assets and harvest-stage borrowing.

[9] Hausman tests do not reject exogeneity of this variable.

access to greater amounts of consumption credit or household savings will have a greater capacity to absorb risk (Eswaran and Kotwal, 1990). This implies that the smallest landowners will be most risk averse, as interest and collateral terms will be least favourable for them. Moreover, even if loan terms were identical, small owners will perceive loans as both more risky and more expensive than larger farmers do: if a loan exhausts the collateral, the borrower will be able to resort to additional credit (insurance) only on more adverse terms (Binswanger and Sillers, 1983). Ownership of assets that cannot serve as collateral may also affect risk behaviour. In the absence of credit, households will be more willing to take up high-risk activities if (near) liquid asset holdings are large, providing a buffer for consumption shortfalls (Dercon, 1996). Evidence presented by Rosenzweig and Binswanger (1993) and Rosenzweig and Stark (1989) on India's SAT supports the above reasoning that wealthy households take more risk.

The prices and wages used are village averages. The estimates include only current-stage female wage rates and the price of one major cash crop per village. Inclusion of more than one output price or wage rate caused multicollinearity problems. The crop prices used are weighted averages of the past prices for three years. Besides wage rates and output prices, the estimates include prices for the other major farm inputs besides labour: bullock traction and inorganic nitrogen. Moreover, the empirical model covers the share of irrigated area as a proxy for land quality[10] and a time trend to account for exogenous developments over time.

The estimated labour supply functions are village-specific in order to account for the differences in the production environments (see Table 3.2. for descriptive statistics).[11] Unless we impose unrealistic restrictions on the utility function, neither the model nor economic theory dictates the functional form of the labour-supply functions. Hence, several forms that use only limited degrees of freedom were tested: linear, log-linear, and double logarithmic. Since the logarithmic equations did not give normally distributed residuals, the linear form was selected.

Note that the model predicts total household labour supply and not just market labour supply. Estimation of market labour supply would imply corner solutions: not all households supply labour to the market. Corner solutions signify the use of truncated regression

[10] Inclusion of expected production computed from the *ex ante* production function (Table 3.1) did not increase the explanatory power of the labour supply functions.

[11] Chow tests reject equality of the village-specific equations at the 1% significance level. When all other coefficients are allowed to differ between the two villages, equality of the riskiness coefficients is not rejected at the 10% significance level, while equality of the income coefficient is rejected at the 5% level.

techniques. These are less powerful than the standard least-squares techniques, which can be used for estimating total labour supply. Fixed-effect regression is applied to allow for unobserved individual effects that may be correlated with the regressors. The individual effects cover, *e.g.*, pure risk preferences, time preferences, self-employment opportunities, and interest rates.[12] Two-stage least-squares estimation accounts for the endogeneity of full income. Estimation instruments are the planting-stage variables (see appendix 3 for first-stage estimates).

Table 3.2. Description of the households (1979-1984)[a]

	Aurepalle (N=152)		Kanzara (N=124)	
	mean	standard dev.	mean	standard dev.
Labour supply				
planting stage (hrs)	680.622	499.581	1331.65	661.246
harvesting stage (hrs)	1193.62	1098.85	1887.57	1195.39
Labour endowment				
adults	3.98026	1.79207	3.99194	2.30410
Agricultural resources				
cultivated area (ha)	3.21575	2.60915	2.68162	2.51551
irrigated area/cultivated area	0.08115	0.12345	0.01556	0.05214
inherent riskiness of land (γ)	117.814	52.1803	388.760	168.978
Prices				
female planting wage (Rs/hr)	0.38518	0.12166	0.38651	0.12256
female harvest wage (Rs/hr)	0.39009	0.12028	0.34092	0.11539
bullock price (Rs/hr)	1.31019	0.14500	2.16925	0.22181
nitrogen price (Rs/kg)	5.96053	0.50986	6.33089	0.78239
paddy price (Rs/kg)	1.43855	0.01684		
cotton price (Rs/kg)			5.58742	0.19164
Assets and income				
land ownership (ha)	5.63645	6.98011	2.36065	1.97815
livestock (Rs)	4254.65	4134.12	1211.88	1316.54
liquid assets (Rs)	7507.63	9154.46	1437.79	1638.19
harvest full income (Rs)	10922.1	7432.37	8173.00	5478.33

Note: [a] All monetary values are in 1983 prices.

3.4.2. Labour supply estimates

The estimates of the labour supply functions provide some interesting insights regarding the relation between risk and labour supply (Table 3.3). The households actively used family labour to manage risk. There were, however, clear differences between the villages. Before

[12] Hence, I assume that interest rates are household-specific and time-invariant. For computing harvest-stage full income, I set the interest rate to zero. The outcomes are not sensitive to assumptions about interest rates: the correlation between full income at interest rates of 0% and 100% is as high as 0.95.

discussing these results in detail, the effects of the other variables in the labour supply functions are examined.

Table 3.3. Fixed effect estimation of labour supply (1979-1984)

Variable	Aurepalle		Kanzara	
	planting (N=152)	harvesting (N=152)	planting (N=124)	harvesting (N=124)
Labour endowment				
adults[a]	112.509***	431.775***	288.274***	712.433***
	(40.8407)	(83.4222)	(83.6600)	(220.005)
Agricultural resources				
cultivated area (ha)	12.2168		43.9239	
	(26.7681)		(42.7374)	
irrigated/total cultivated	-545.248		2468.12	
	(424.083)		(1446.98)	
inherent riskiness of land (γ)	3.76606*		-0.56186	
	(2.12674)		(0.96379)	
Prices				
wage rate (Rs/hr)	16996.2***	1189.15	1909.34	-862.033
	(4090.76)	(1332.28)	(2579.04)	(2137.34)
bullock price (Rs/hr)	-3167.87***		-1209.18	
	(729.521)		(2189.55)	
inorganic nitrogen price (Rs/hr)	-330.673***		202.685***	
	(115.695)		(61.2392)	
paddy price (Rs/kg)	-3321.92*			
	(1904.09)			
cotton price (Rs/kg)			1330.91	
			(959.053)	
Assets and income				
land ownership (ha)	12.7041	-52.1358**	146.574	15.2171
	(32.1759)	(25.0995)	(107.550)	(149.357)
livestock (1000 Rs)	-5.69694	-2.40994	-34.6642	524.046***
	(9.91512)	(13.0076)	(92.6986)	(176.945)
liquid assets (1000 Rs)	11.1047	2.22085	24.0523	102.741*
	(7.07361)	(9.06029)	(43.7988)	(59.1014)
full income (1000 Rs)[b]		-78.0733***		-348.759***
		(21.4772)		(117.145)
year	-892.489***	-183.952**	-180.847	80.6725
	(199.382)	(74.1183)	(348.778)	(97.1142)
Adjusted R^2	0.74	0.93	0.52	0.24

Notes: [a] Equality of the coefficients for men and women could not be rejected at the 8% level for Aurepalle harvest labour supply and at the 10% level for the other equations.
[b] Instruments are used for this variable (see Appendix 3 for the first-stage estimates).
White/Heteroscedasticity corrected covariance matrices used.
Standard errors are in parentheses.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

As expected, labour endowment was a major determinant of household labour supply. For Kanzara farmers, there was only one other significant variable in the planting stage: the fertiliser price. There was no difference between the effect of an additional man or woman in either village. The negative time trend in the Aurepalle equations may reflect the tightening of the labour market, which reduced the probability of unemployment.

Asset levels had only a limited impact on family labour supply. Land ownership had a negative impact on harvest labour supply in Aurepalle. Large landowners could smooth consumption through means other than increasing harvest labour supply. Nevertheless, liquid assets did not significantly affect planting labour supply in either village. This suggests that short-term credit constraints were not a problem. Surprisingly, the relation between liquid assets and harvest-stage labour supply was positive in Kanzara. The same holds for livestock. Possibly, farmers needed additional income to feed their livestock throughout the dry season.

Both wage rates and other prices affected labour supply. The wage elasticity was positive for Aurepalle planting labour and not significant in the other equations. An increase in fertiliser prices increased labour supply in Kanzara. This could result from a decrease in the profitability of crop production associated with a rise in input prices. This is, however, far from obvious given the insignificance of the other production-related variables. In Aurepalle, where fertiliser use was less widespread, the fertiliser price elasticity was negative, as was the bullock price elasticity. This indicates that input prices pick up something other than just production costs. Bullock prices, *e.g.*, affect not only production costs, but also potential income from renting out bullocks. Because of their impact on crop profits, output price elasticities were expected to be negative. However, the observed effects were insignificant, presumably because of the large wealth of crops cultivated.

Risk affected planting labour supply only in Aurepalle: the risk elasticity of planting labour supply was 0.65 (see Table 3.4). In other words: Aurepalle households increased labour supply in response to production risk. Thus, they guaranteed a certain income when yields were still erratic. This is the *ex ante* risk-management strategy mentioned in sections 3.1 and 3.2. Risk behaviour may also explain the negative coefficient for irrigation: higher irrigation implies a smaller chance of very low yields. The results do not confirm the use of family labour for *ex ante* risk management in Kanzara.

On the other hand, the estimates show evidence of the use of family labour for *ex post* risk coping in both villages: households increased their harvest labour supply when full income declined. The income elasticity of labour supply was –0.71 and –1.51 in Aurepalle and Kanzara, respectively (see Table 3.4). This corresponds to compensating 4 and 21% of the losses in income through increases in labour supply. In other words, Kanzara households actively used family labour for *ex post* risk coping, while Aurepalle households used this strategy only marginally.

Table 3.4. Household labour supply strategies with respect to risk (1979-1984)

	Aurepalle	Kanzara
Ex ante		
risk elasticity	0.65*	-0.22
Ex post		
income elasticity	-0.71*	-1.51***
% of crop profit loss compensated	4*	21***

Notes: Elasticities are calculated for group means.
* and *** indicate significance at the 0.10 and 0.01 levels, respectively.

These results indicate that the households in the two villages had different risk strategies: Kanzara households used family labour to stabilise income *ex post* only. Aurepalle households made little use of the *ex post* strategy, but used family labour extensively for *ex ante* risk management. The latter strategy is more costly in terms of utility, as it requires stabilising measures before the results of the stochastic process are revealed. The explanation of these differences starts from the difference in *ex post* smoothing.

There are two possible explanations for the *ex post* difference: i) because of the larger availability of informal consumption credit, households in Aurepalle may have been less inclined to sacrifice home time in order to stabilise income than their counterparts in Kanzara; ii) employment opportunities in Aurepalle were too limited to allow much *ex post* stabilisation through the labour market. The first explanation alone cannot account for the behavioural difference. The higher income variability in Aurepalle translated into higher consumption variability. There is no reason to believe that Aurepalle households had smaller stability preferences than households in Kanzara. What is more, this hypothesis is rejected on the basis of the results for the planting stage. Hence, labour market constraints explain at least part of the difference: in Aurepalle, employment was scarce in the second part of the harvest stage, while in Kanzara, agricultural employment was spread relatively evenly over the year and there was a public-works programme.

The above presents part of the explanation for the *ex ante* difference. Production risk was higher in Aurepalle. We could, therefore, have expected more intensive risk management strategies in Aurepalle than in Kanzara. Moreover, Aurepalle households were less able to compensate crop losses *ex post*, as explained above. This increased the necessity for *ex ante* risk management even more. Hence, labour supply in the planting stage cannot be considered without regard to the possibilities to generate income in the harvesting stage.

3.5. Conclusion

In this chapter, a two-stage farm-household model was presented that provides insights into the seasonal determinants of labour supply under risk and credit constraints. The model shows that households increase labour supply at the cost of home time when crop income turns out to be low (*ex post* risk coping). The effect of risk on growing-season labour supply is ambiguous and depends on crop technology and household preferences. Possibly, households will work long hours in order to guarantee a certain consumption floor (*ex ante* risk management). Previous research either drops risk from the empirical analysis because of the unrealistic assumption of perfect lifetime credit markets or only covers the two risk-management strategies in isolation.

Besides, there has been a focus on labour supply to the market as compared to total labour supply. An increase in off-farm labour supply is not equivalent to sacrificing home time to compensate for an income shock. After a negative shock, less labour is required for on-farm harvesting activities. This in itself will lead to a shift to off-farm employment. Moreover, a focus on off-farm labour supply implies the use of econometric techniques that allow for corner solutions. These techniques are less powerful than least-squares regression.

The measures used to demonstrate risk management differ from those used in previous studies. The model shows that it is not necessary to estimate the unanticipated income shock to demonstrate *ex post* smoothing. If it is possible to single out harvest-stage labour supply, it is sufficient to determine the household's reaction to actual harvest-stage full income. However, we do need a measure of production risk to show the *ex ante* effects of risk. Instead of time series of production, the Just-Pope two-stage method from the production literature was used to estimate the standard deviation of production. The advantages of this method are twofold: i) it includes as much information as possible on the actual production situation that is available to the farmer at planting; ii) it does not require panel data (although it can accommodate them, as it does in this study).

Empirical estimates for the two study villages confirm the use of family labour for *ex ante* risk management as well as *ex post* risk coping. These results have important implications for research on the cost of income uncertainty for farm households. While most of this research focuses on the role of savings and assets on consumption smoothing, family labour may be at least equally important. The costs of income uncertainty are at least partly reflected in decisions that affect the households labour endowment, including migration, education, and fertility. Moreover, interventions in labour markets may significantly improve the economic security of farm households. These interventions may be indirect — through health programs that enhance the ability of individuals to engage in physical employment — or direct — through public works programs.

The results give an indication of the short-term impact of the latter, as they present information about household behaviour in two different villages. In one of the villages, households had access to a year-round public-works programme. In the other village, there was no such programme and dry-season employment is limited. The households in the first village had a greater capacity to smooth income *ex post*. Risk induced the households in the latter village to work long hours in the planting stage, by way of compensation. This implies that these households sacrificed additional home time for *ex ante* risk management.

The question remains whether the households sacrificed not only not only home time, but also crop profits. In the absence of sufficient possibilities to compensate for yield losses *ex post*, households may try to prevent large losses by choosing relatively stable, but low-return crop technologies. In this case, dry-season employment projects could stimulate farm households to increase crop income. This could put upward pressure on agricultural labour demand. In a situation where there is (some) year-round unemployment, dry-season employment projects could, thus, indirectly decrease cropping-season unemployment. Similarly, these projects could stimulate fertiliser use, which affects not only household income but also the sustainability of agricultural production. These issues are dealt with in the following two chapters.

4. FARM AND NONFARM EMPLOYMENT: COMPLEMENTS OR SUBSITUTES? *A Case Study of India's Semi-Arid Tropics*

In order to absorb the increasing population of India's rural SAT, agricultural employment should expand continuously. Nonfarm employment policies are likely to affect agricultural employment, as the main agricultural employers, smallholders, are also important suppliers of market labour. These smallholders face high production risks and limited availability of credit. Wage income as well as liquid asset holdings affects their capacity to cope with risk. Nevertheless, previous research has tended to ignore the interactions between wage income and farm labour use. Using the model presented in Chapter 3, this chapter disentangles the ambiguous relations between risk, credit constraints, family labour, and agricultural labour use. Empirical estimates for the two study villages in India's SAT show that, depending on the production environment, risk can both increase and decrease labour use. However, there is no compelling evidence of short-term credit constraints. The estimates confirm the hypothesis that off-farm employment opportunities affect farm labour use, but the direction of the effect is ambiguous.

4.1. Introduction

The majority of the rural people living in India's semi-arid tropics (SAT) depend heavily on dryland agriculture for their livelihood (Walker and Ryan, 1990). Not only is crop production an important income source for landed households, it also provides the lion's share of rural employment. The latter is important for cultivators as well as for the landless: most farm households earn a significant share of their income through wage employment. Unless employment growth keeps pace with population growth, the number of people living in poverty will increase significantly in the coming years.

Walker and Ryan (1990) are pessimistic about the prospects for significantly absorbing more labour in dryland agriculture in India's SAT. They see considerable potential in the more favourable areas, but pin their hopes for labour absorption in rainfall unassured areas mostly on an expansion in irrigated areas. As the perspectives for such an expansion are bleak, the growth in nonfarm labour demand must accelerate to decrease the supply of labour to the agricultural labour market. Employment in nonagricultural sectors is, however, limited and is expanding too slowly to absorb population growth (Ratna Reddy, 1995). Consequently, the growth of agricultural employment remains an essential factor in alleviating poverty.

Agricultural employment is likely to be affected by production risk, which is a pervasive characteristic of developing country agriculture in general, and of SAT agriculture in particular. The relation between production risk and employment becomes especially interesting in the light of studies showing that technological progress has increased production risk over time (*e.g.*, Hanumatha Rao *et al*, 1988). Nevertheless, attempts to include production risk explicitly into analyses of labour demand are rare.

Notable exceptions are Skoufias (1993) and Kanwar (1999). Skoufias explicitly incorporates yield risk in his analytical model, but not in his empirical estimates. Kanwar tries to empirically determine the effects of risk, but his perception of the impact of risk is rather narrow. He argues that a marginal increase in risk will cause a decline in the demand for labour, given decreasing absolute risk aversion and a well-behaved production function. However, this relation only holds when an increase in input use implies an increase in production risk. This is not necessarily the case (Just and Pope, 1979). In practice, the marginal risk effect of an input depends on the specific production technology and the biophysical environment (Hanus and Schoop, 1989; Smith and Umali, 1985). Consequently, aggregating male and female labour and pooling farmers facing different production environments, as Kanwar does, may average out the diverse effects of risk.

A second characteristic of developing country agriculture that is mostly ignored in studies of labour use is the imperfection of credit markets. Skoufias (1993), *e.g.*, assumes that Indian farmers face perfect financial markets over their lifetime. This strong assumption is not supported by empirical evidence. Despite the wealth of financial infrastructure, long-term credit is scarce in India. Consequently, farmers are not able to offset fluctuations in crop returns through changes in assets and liabilities (Ravallion and Chauduri, 1997). On the other hand, empirical evidence on short-term credit constraints is mixed (*e.g.*, Kochar, 1997; Binswanger and Khandker, 1993).

Production risk and credit constraints affect labour supply as well as labour demand. Indian smallholders not only provide the lion's share of rural employment, but also a significant share of market labour. It was shown in Chapter 3 that the resulting wage income helps to reduce the variance of overall household income. Households that are better able to cope with risk are more likely to invest in profitable, but risky, crop technologies. In addition, prudent or credit-constrained farmers may use wage income to finance input purchase. Consequently, there may be a strong relation between wage income and agricultural productivity and employment. The studies described above do not consider this potentially important role of wage income in labour use decisions.

The impact of wage income on crop production is highly relevant when designing employment policies. The introduction of public-works programmes or small-scale industries may lead to a change in agricultural production technologies and, thus, agricultural employment. Increased nonfarm employment results in a tightening of the labour market and may, hence, cause a rise in wage rates. Although evaluations of employment programmes generally recognise this direct effect, they ignore the indirect effects through risk and liquidity described above (*e.g.*, Datt and Ravallion, 1994). Consequently, these evaluations may well be biased.

This chapter shows the simultaneous impact of risk, credit constraints, and off-farm employment on agricultural labour use in two villages in India's SAT. The structure of the chapter is as follows. Section 4.2 describes labour use in the survey villages. Moreover, it elucidates the effects of risk, credit constraints, and family labour on farm-labour within the framework of the model from Chapter 3. The combined impact of these factors is essentially an empirical matter. Section 4.3 presents empirical estimates of labour use in the study villages. Conclusions are presented in Section 4.4.

4.2. Agricultural employment in India's SAT

4.2.1. Crop labour use in the study villages

Three previous studies address the determinants of agricultural labour use in the ICRISAT villages. Walker and Ryan (1990) present two regressions that give a first impression of the determinants of labour use in crop production, while Skoufias (1993) and Kanwar (1999) estimate reduced form labour demand functions derived from farm-household models. The remainder of this section presents the major findings of these studies.

Walker and Ryan regressed labour intensity on a time trend in years and found a significant negative trend for Aurepalle and a significant positive trend for Kanzara. They argue that the reason for the positive trend in Kanzara was a shift to more labour-intensive cropping patterns, particularly the substitution of mung bean, intensive in its demand for women's labour for weeding, for local sorghum in upland cotton intercropping systems. The significant negative trend for labour intensity in Aurepalle could be the result of two effects: i) between 1983 and 1985, *i.e.*, at the end of the survey period, annual rainfall was below average; ii) real wages rose during the survey period.

In an additional analysis, Walker and Ryan regressed labour use per hectare on the household resource endowment controlling for soil quality and year-to-year variability. The results indicate that, especially in Aurepalle, the extent of irrigation played a dominant role in determining the demand for labour. The high labour requirement for cotton, the dominant rain-fed crop in Kanzara, explains the small size of the irrigation coefficient in this village. Moreover, the main irrigated crop in Aurepalle, paddy, requires more labour than the irrigated cropping systems of Kanzara. The coefficients for bullocks were positive. This is consistent with the observation that bullock hire markets may not be well developed due to the covariance in the demand for animal traction. Cultivated area only had a significant effect on labour use intensity in Kanzara, where 12% of the area is under sharecropping. The effect of family workers was not significant in Kanzara and four other villages that Walker and Ryan considered. Only in Aurepalle was there a significant negative coefficient. Walker and Ryan interpreted this as support for the hypothesis that the daily-rated labour markets in the villages worked fairly well and were reasonably competitive: labour market imperfections would result in significantly positive coefficients. The negative coefficient for Aurepalle remains unexplained.

Skoufias developed an intertemporal model of household behaviour under risk and estimated the planting- and harvest-stage labour demand functions derived from the model. The independent variables are wage rates, fixed inputs, and individual effects. The model is formulated such that risk and household preferences are included in the individual effect. Credit markets are assumed to be perfect over the household's lifetime. In his empirical model, Skoufias added a number of land quality and weather indicators. Intriguingly, he treated fertilisers as a land-augmenting improvement determining labour utilisation and not as an alternative variable input. The regression results indicated that the demand for male labour in pre-harvest activities had an elastic response to changes in the male wage rate. On the other hand, the use of female labour was unresponsive to changes in wage rates. Moreover, more planting labour was applied on irrigated plots and on plots where fertilisers and/or pesticides were used.

Kanwar estimated the total demand for labour as well as the demand for hired labour. His regression equations are based on a static farm-household model, which assumes that all inputs increase risk and that within-year credit markets are perfect. The main explanatory variables are wage rates, household composition, resource endowment, and the (historical) mean and standard deviation of net returns. Expenditures on variable inputs other than labour are considered an exogenous technology factor. The estimates did not distinguish between planting and harvesting labour or male and female labour. The real wage rate was found to have a significant negative effect on both total and hired labour demand. Household composition affected the demand for hired labour, but not total labour demand. The impact of nonland assets and variable inputs was significantly positive as expected, but production risk was not found to affect labour use.

The above studies ignore potential credit constraints, but give a first impression of the effects of risk and the family labour endowment on labour use in crop production. In Skoufias' study, all differences in risk behaviour are taken up by the individual effect. This is computationally convenient, but does not shed light on the precise effects of risk on labour use. Kanwar included explicit measures of risk and family labour in his regressions of total labour use. He did not find significant effects of either factor. However, as mentioned before, the absence of a distinction between male and female labour and the pooling of farmers in very different regions may obscure the results. Walker and Ryan, on the other hand, found a significantly negative relation between the household labour endowment and labour use in crop production in Aurepalle. They did not consider production risk, and the negative impact of labour endowment on labour use remains unexplained. The absence of a comprehensive overview of all relevant relations between labour endowment and labour use is probably at least partly to blame for this lack of explanation. Moreover, the results obtained may be biased, as the regression does not include any independent variables other than resource endowments.

4.2.2. Crop labour and production risk

In order to show the ambiguity of the impact of risk on labour use, the two-stage farm-household model described in the previous chapter was used. The advantage of this two-stage model over Kanwar's static model is that it reveals the impact of risk and family labour on the use of crop labour in greater detail. Planting-stage decisions are made under uncertainty, while the harvest stage can be used to cope with the consequences of the outcome of the stochastic process. Moreover, the model allows for risk-decreasing as well as risk-increasing inputs. Whether labour increases or decreases risk depends on the specific activity and production environment at hand.

The model in Chapter 3 shows that farmers can adapt the use of crop labour, the major agricultural input, in order to stabilise household income. Recall the first-order conditions for the planting stage:

$$f_{L_1} = \frac{w_1}{p}\frac{U_{C_1}}{\rho E\left(U_{C_2} g_{Q_1}\right)} - h_{L_1}\gamma\frac{E\left(U_{C_2} g_{Q_1}\varepsilon\right)}{E\left(U_{C_2} g_{Q_1}\right)}, \tag{4.1}$$

$$U_{\ell_1} = w_1 U_{C_1}, \tag{4.2}$$

$$U_{C_1} = \rho(1+r)EU_{C_2} + \lambda, \tag{4.3}$$

$$\lambda \geq 0, \tag{4.4}$$

$$B \leq B_m(Z). \tag{4.5}$$

Combining Eqs (4.1) and (4.3) gives

$$f_{L_1} = \frac{w_1(1+r)}{p}\frac{EU_{C_2}}{E(U_{C_2}g_{Q_1})} + \lambda\frac{w_1}{p\rho E(U_{C_2}g_{Q_1})} - h_{L_1}\gamma\frac{E(U_{C_2}g_{Q_1}\varepsilon)}{E(U_{C_2}g_{Q_1})}. \tag{4.6}$$

This equation demonstrates the impact of risk and credit constraints on the use of labour in crop production.

First, consider a household that is not credit constrained (λ=0). Production risk affects planting-labour use, and the sign of the effect equals the sign of the marginal risk effect of labour, h_{L1}. This is easily understood as follows. The value of the marginal product of labour does not equal the discounted wage rate, even after correcting for harvesting costs.[13] The difference is a correction factor that covers the joint effect of household risk preferences and the marginal risk effect of labour. The sign of the correction factor is ambiguous. Let us first consider the numerator of the ratio. Following Kanwar (1999), note that a rise in ε involves a rise in planting-stage produce and thus profits and harvest consumption, C_2. Given risk aversion, this implies a decrease in the marginal utility of harvest consumption, U_{C1}. Likewise, a rise in ε involves a decrease in the marginal productivity of planting produce, g_{Q1}. Consequently, $E(U_{C2}g_{,Q1}\varepsilon)$<0. As $E(U_{C2}g_{Q1})$ is positive, the sign of the correction factor is thus opposite to the sign of h_{L1}. The latter factor is ambiguous: h_{L1}>0 if labour use increases risk, while h_{L1}<0 if labour use decreases risk. In other words, risk increases labour use if labour is risk decreasing and *vice versa.*

The sign of the marginal risk effect of labour depends on the production technology and the biophysical environment (Hanus and Schoop, 1989). The impact of labour on production risk may even vary according to the specific activity executed. A study on Philippine rice production illustrates the richness in possible relations (Antle and Crissman, 1990). Crop establishment labour, for example, decreases yield variability for modern varieties, while for traditional varieties, establishment labour increases variability in some years but has no effect in other years. Land preparation labour is uniformly risk-reducing, whereas labour devoted to pest and weed management and irrigation activities does not affect yield variability. Finally, increasing management attention reduces the chance of very low yields. The estimates from Chapter 3 indicate that female labour is risk-increasing in Kanzara. If we ignore the high standard errors of the other labour coefficients in the variance functions, we could say that both male and female labour are risk-increasing in Aurepalle and that male labour is slightly risk-decreasing in Kanzara. Nevertheless, previous research has shown that farmers perceptions do not necessarily coincide with the technical relations observed (see Section 3.3.1).

In the presence of credit constraints (λ>0), the household may not be able to attain maximum expected utility as described in the previous paragraphs. If credit demand exceeds credit availability, the household will take the maximum loan possible and allocate resources and consumption accordingly. Hence, the household consumes less in the planting stage and uses less planting-stage labour in production than it would in the absence of a credit constraint. Whether or not credit constraints are binding depends not only on exogenous factors like the household credit reserve, their land size, and the riskiness of their land, but also on their preferences. Prudence may limit borrowing because farmers want to avoid repayment requirements after a bad harvest (Deaton, 1997).

The above indicates that the family labour endowment will affect crop labour use. Chapter 3 has shown that farm households in the survey villages use family labour to smooth household income. The results, however, do not establish a direct relation between short-term credit constraints and labour supply. When the family labour endowment moderates risk and (possibly) credit constraints, this will affect the use of labour in crop production. The sign of the foreseen effect is ambiguous and depends on the relative importance of risk and credit constraints and the nature of the risk effect of labour.

[13] The corrected output price is $p\dfrac{E\left(U_{C_2} g_{Q_1}\right)}{EU_{C_2}}$.

4.3. Risk, credit constraints, and labour demand

4.3.1. The empirical model

The reduced form equation for planting-stage labour use derived from the analytical model is as follows:[14]

$$\frac{L_1}{A} = F(A, p, w_1, w_2, r, \gamma, T_1, T_2, \rho, Z). \qquad (4.7)$$

The main variable of interest in this equation is γ, the inherent riskiness of the land. This variable represents the expected standard deviation of crop production prior to decisions on input use and is therefore exogenous to the equation. The determinants of γ are related to land size, land quality and weather expectations (see section 3.3.1).

Nonseparability of the model is reflected in the presence of consumption as well as production characteristics of the household. In the absence of risk (or risk aversion) and credit constraints, production and consumption decisions would be separable and the farmers would simply maximise risk. This results in the following labour use function:

$$\frac{L_1}{A} = F(A, p, w_1, w_2, r). \qquad (4.8)$$

As the two empirical models are nested, we can easily test for separability. Rejection of the separability hypothesis proves that at least one market is imperfect, but does not indicate which market this is. Hence, we must interpret the coefficients of the various utility related variables with care.

The model assumes perfect labour markets and hence rules out what is probably the best-known effect of family size on labour use: the consequences of labour market dualism. In the presence of hiring frictions and unemployment, the effective wage rate of hired labour is higher than that of family labour. *Ceteris paribus*, this results in a higher labour intensity in crop production for larger families (Benjamin, 1992). However, despite the existence of some (seasonal) unemployment, this relation is generally assumed to be irrelevant in the study area.

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[14] See section 2.5.2 for more information about the reduced form approach to estimating nonseparable household models.

The estimates, moreover, provide a test for the assumption of perfect labour markets: it is not rejected if the coefficients for labour endowment are not uniformly positive.

The functional form of the labour use function is ambiguous. The Cobb-Douglas function was used in the present study. This functional form accounts for decreasing marginal returns and is linear in its parameters. The use of male and female labour were estimated separately, as all pre-harvest activities are gender-specific. Distinct equations were also estimated for the two villages.[15] Different production environments may lead to opposite relations between risk and labour use. Moreover, Chapter 3 has shown that the income-smoothing capacity of labour differs between the two villages.

The equations were estimated with least-squares techniques accounting for the panel character of the data. The estimates allow for correlation between the individual effect and the independent variables. The individual effect covers several variables that are assumed to be time-indifferent: the household-specific interest rate, pure risk preferences, and time preferences. The presence of year effects is rejected in all equations.

Two-stage least-squares regression is used to correct for endogeneity of the share of irrigated area in the Aurepalle equations. Hausman tests did not reject the exogeneity of the share of irrigated area in Kanzara and of cultivated area and liquid assets in either village. Large farmers in the later years of the study period distort normality of the residuals in the Aurepalle equations: these farmers used much less labour than the average function suggests. Labour markets have tightened over the years, which has caused large farmers to resort to less labour intensive technologies. Inclusion of a dummy solved the normality problem.[16]

The data required for estimation of the labour supply functions were collected during the entire ten years of the survey (see Table 4.1 for descriptive statistics). For the labour supply functions, only the last six years could be used. This allowed calculation of expected output prices as weighted averages of prices during the previous three years. As this procedure would lead to a loss of three years of labour use data, it was assumed that expected prices equal previous year village averages. The larger sample size compared to Chapter 3 allows inclusion of the prices of more than one important crop: paddy and castor in Aurepalle, cotton in Kanzara, and pigeon pea and sorghum in both villages. Nevertheless, multicollinearity precludes inclusion of more than one wage rate per equation. Finally, the regressions cover a proxy for land quality, which represents yield expectations prior to

[15] Chow tests reject equality of the labour use functions for two villages at the 1% level.

[16] The dummy is 1 if the cultivated area is larger than 5 ha in the years 1981-1984, zero otherwise.

decisions on input use. The proxy equals the predicted value of the mean production function from section 3.3.1 divided by cultivated area. In order to ensure that this variable is fully exogenous, I use per hectare averages of input use to calculate predicted output.[17]

Table 4.1. Descriptive statistics of the farm households (1976-1984)

	Aurepalle (N=234)		Kanzara (N=241)	
	mean	standard dev.	mean	standard dev.
Labour use (excl. harvesting)				
male labour (hrs)	474.962	553.534	695.759	792.579
female labour (hrs)	373.825	640.689	832.365	1079.40
Agricultural resources				
cultivated area (ha)	3.41685	2.82188	5.47773	6.85483
irrigated area/total area	0.10039	0.17233	0.03326	0.11424
expected yield (Rs/ha)	1026.34	519.928	1006.45	354.185
inherent riskiness of land (γ)	120.383	49.7327	583.295	369.297
bullock owned (yes=1)	0.63248	0.48316	0.56847	0.49632
Prices				
male wage (Rs/hr)	0.60779	0.19767	0.78255	0.08915
female wage (Rs/hr)	0.41141	0.13095	0.44300	0.07911
bullock price (Rs/hr)	1.40599	0.21640	2.18696	0.26335
nitrogen price (Rs/kg)	5.90368	0.51799	6.57948	0.90827
Household assets				
liquid assets (Rs)	5187.73	7531.04	5726.81	11189.6
land owned (ha)	5.72923	7.30246	5.07137	6.38470
livestock (Rs)	4330.92	4294.80	2044.05	2551.56
Labour endowment				
adults	3.75641	1.62216	4.16598	2.16733

Note: All monetary values are in 1983 prices.

Prior knowledge indicates that there may be several structural breaks in the estimates for Kanzara. First, Chapter 3 indicates that the labour-supply behaviour of very large farmers deviated from that of the rest of the farmers. Second, the public-works programme was not introduced until 1979. Nevertheless, the structural breaks at 8 hectares and 1979 were not statistically significant at the 5% level, so the complete sample was used for the estimates.

4.3.2. Labour-demand estimates

Table 4.2 presents the results of the labour-use regressions. The focus of interest is the effects of risk and family labour on crop-labour use. The estimates reveal that the effects were diverse and differed between the two villages and the type of labour considered. This section starts with clarifying how risk and the nature of the labour market caused these diverse

[17] As irrigation is an important determinant of input use in Aurepalle, I used three different levels of input use per hectare for this village: input use without irrigation, input use with less than half of the area irrigated and input use with over half of the area irrigated.

effects. Household behaviour in Kanzara is contrasted with household behaviour in Aurepalle. Next, the section briefly analyses the effects of the other independent variables on labour use.

Table 4.2. Fixed effect estimates of labour use in the study villages (1976-1984)

	Aurepalle (N=234)		Kanzara (N=241)	
	ln(male hrs/ha)	ln(female hrs/ha)	ln(male hrs/ha)	ln(female hrs/ha)[a]
Agricultural resources				
ln(cultivated area)	0.29882**	0.24811	-0.47644***	-0.28791***
	(0.13787)	(0.16081)	(0.11507)	(0.07223)
irrigated area/total area[b]	0.65324	4.06439***	-0.53492**	-0.42942
	(0.57166)	(0.72628)	(0.28592)	(0.33281)
ln(expected yield)	0.74438***	1.13657***	-0.15927	-0.33227*
	(0.20758)	(0.21269)	(0.14716)	(0.19694)
ln(riskiness land (γ_i))	-1.08527***	-1.21460***	0.73287***	
	(0.29750)	(0.36005)	(0.26343)	
bullock owned (yes=1)	-0.07297	-0.00956	0.13584*	-0.00798
	(0.09447)	(0.09394)	(0.07921)	(0.10062)
Prices[c]				
ln(wage rate)	-1.43102	1.22148	0.84813	0.53334
	(1.34363)	(0.83288)	(0.71472)	(0.41688)
ln(bullock price)	0.19114	-0.67579	0.30194	-1.32335**
	(0.86984)	(0.43908)	(0.47708)	(0.55178)
ln(nitrogen price)	-0.31159	2.23096	-0.59827*	-0.48392
	(0.71975)	(1.56026)	(0.31350)	(0.48793)
Household assets				
ln(liquid assets)	0.03806	0.09967*	0.07877**	
	(0.05551)	(0.06012)	(0.03161)	
ln(land owned)	0.01495	0.09061*	-0.14799*	
	(0.03575)	(0.04927)	(0.08759)	
ln(livestock)	0.04655*	0.04067	-0.00983	
	(0.02699)	(0.04035)	(0.02167)	
Labour endowment				
ln(adults)[d]	0.22737	0.12546	-0.22600**	
	(0.15616)	(0.17992)	(0.09896)	
year	0.12574	-0.35184***	0.08254***	-0.04330
	(0.18860)	(0.11764)	(0.02941)	(0.03353)
dummy[e]	-1.14919***	0.02699		
	(0.16399)	(0.12195)		
Adjusted R^2	0.64	0.83	0.42	0.36

Notes: [a] Profit maximisation could not be rejected at the 10% level.
[b] Instruments are used for this variable in the Aurepalle equations (see Appendix 3).
[c] Expected prices for the following crops were included in the regression, but not in the table: pigeon pea, sorghum, paddy (Aurepalle), castor (Aurepalle), and cotton (Kanzara). Expected prices are assumed to equal the village level average price during the previous year.
[d] Additional inclusion of the log of men or women or the ratio of men to women yielded coefficients for these variables that were not significant at the 10% level.
[e] dummy =1 if year >80 and cultivated area>5 ha; 0 otherwise.
Standard errors are in parentheses.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

In Kanzara, production risk led to an increase in the use of male labour. Apparently, farmers used male labour to decrease production risk. This coincides with the findings for paddy production in the Philippines (Antle and Crissman, 1990). In the study area, major male tasks are land preparation and supervision. Both were shown to increase yield stability in the Philippines. Nevertheless, the production function estimated in chapter 3 does not provide much support for this relation. Although the coefficient for male labour in the variance function is negative, it is very low and insignificant. Nevertheless, the village farmers seem to consider male labour as a risk-increasing input. The negative coefficient for land ownership confirms this perception. As wealthier households were better able to manage risk, their need to use male labour to decrease yield risk was lower.

The above relation between risk and labour use implies that the effects of risk and credit constraints on crop-labour use were opposite. Land ownership is a major determinant of access to credit. An increase in land ownership will, therefore, *ceteris paribus* increase the availability of loans. The positive relation between land ownership and labour use thus indicates that supply limits did not constrain the use of short-term production credit. If we compare this finding with the studies presented in Chapter 2, we can conclude that it is consistent with Kochar's assertion that working capital did not constrain agricultural production, as credit constraints did not affect land rental decisions. The results reported by Binswanger and Khandker, which show that the availability of credit institutions increased district level fertiliser use, may be less relevant for the study villages: there was a credit co-operative in both villages.

Unlike land, liquid assets increased the use of male labour. This is consistent with Kanwar's findings for nonfarm assets. Using the reasoning from the previous paragraph, limited borrowing can explain this relation while risk aversion cannot. However, it was argued that credit constraints were not binding. The positive effect of liquid assets on labour use, therefore, mainly resulted from the unwillingness of households to borrow. They preferred spending their own funds to taking a loan, which they must repay even when yields are low.

In line with the previous results, the relation between family labour and labour use was negative. Neither labour market imperfections nor borrowing constraints can explain this relation. Risk management, however, renders an obvious explanation: a higher labour endowment implies a higher capacity to manage risk and, therefore, makes households less inclined to use crop labour to manage risk. It is not surprising that the risk effect of family labour was larger than its effect on liquidity and prudence. Total labour income serves as a risk management tool, while households can use only part of labour income to finance crop production.

The public-works programme appeared to be of minor importance for the risk-management capacity of family labour, as there was no structural break in household behaviour at the introduction of the programme in 1979. Agricultural labour demand was spread relatively uniformly over the year due to the favourable production environment in the rainfall-assured area of Akola. This appears to allow significant *ex post* risk coping through the labour market.

Risk, prudence, and family labour did not affect the use of female labour in Kanzara. A joint F-test for all consumption-related variables in the equation did not reject profit maximisation for this input at the 10% level. Hence, farmers' risk perceptions again deviate from the technical relation between input use and risk as described by the production function estimated in Chapter 3.

The story is different for Aurepalle, where production risk significantly decreased the use of both male and female labour.[18] Remember that risk increased the use of male labour and did not affect the use of female labour in Kanzara. The stabilising effect of monitoring supposedly explains the risk-decreasing effect of male labour. Monitoring was probably less effective in the harsh production environment of Aurepalle. On the other hand, inevitable yield losses due to adverse weather conditions, which imply the loss of most of the costs of inputs used, were more likely to occur in Aurepalle than in Kanzara. Besides, in Aurepalle an important female task was transplanting paddy. This type of labour was found to increase risk in some less favourable production systems in the Philippines. Nevertheless, the coefficients for male and female were not significant in the variance function estimated in Chapter 3.

The different asset categories all have significantly positive coefficients in the Aurepalle equations, indicating that wealthier households used more labour in crop production than their poorer neighbours did. Both risk and borrowing limits can explain this effect. Greater wealth implies that farmers can afford to take more risk in crop production. In Aurepalle, this led to greater use of labour. Moreover, wealthier household were less hesitant to borrow and less likely to face credit constraints. This also allowed them to use more crop labour.

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[18] The inter-village difference between the coefficients for riskiness is significant at the 10% level for male labour.

In contrast to Kanzara, the family labour endowment did not affect labour use in Aurepalle. We might have expected a significant positive effect because, like physical capital, family labour can be used to decrease the impact of risk and credit constraints or prudence. However, as was shown in Chapter 3, Aurepalle households could only adapt family labour supply to production risk in the planting stage. Hence, the effect of family labour on income stability was small in Aurepalle compared to Kanzara, where households could increase labour supply in response to unexpected yield losses. We still need to explain the absence of a significant effect of family labour on household liquidity, and thus on credit constraints or prudence. Only a limited share of total labour income can be pocketed before labour is applied in crop production. It is hence not surprising that the liquidity effect of the family labour endowment on current labour use was small.

The variables not directly related to risk and liquidity management present no surprises. The coefficients for cultivated area may seem to indicate implausibly large scale effects. However, we must keep in mind that an increase in cultivated area involves a rise in production risk. The coefficients for these variables are opposite in all three equations covering risk. Given the amount of production risk, an increase in cultivated area would, for example, induce farm households to increase the intensity of male labour in Aurepalle. However, an additional plot of land is associated with additional production risk. This additional risk will buffer the increase in labour intensity.

The observed time trends confirm the findings of Walker and Ryan (1990). The intensity of female labour shows a negative trend in Aurepalle. Between 1983 and 1985, which was the end of the survey period, annual rainfall was below average. Apparently, this resulted in a low use of labour. In addition, the included dummy shows that the tightening of rural labour markets decreased the availability of hired labour especially for large farmers. Finally, the results confirm the positive trend that Walker and Ryan found for labour use in Kanzara. This positive time trend resulted at least partly from a shift to more labour-intensive crops.

In Aurepalle, labour use was highest on soil with higher expected yields in general and irrigated areas in particular. Land quality had the opposite effect in Kanzara. The use of female labour was lower on soils with higher expected yields, probably because weed growth is less abundant on poorer soils. Besides, irrigated crops require less male labour than dryland crops.

Input prices had only a limited effect on crop labour use. Wage rates were not significant in any of the equations, presumably due to the impossibility of disentangling the effects of male and female wage rates. This is in line with Skoufias' finding of insensitivity to wage rates for female labour. On the other hand, he found that male labour had an elastic response to changes in the male wage rate. Male labour and fertilisers appeared to be substitutes in Aurepalle. The other fertiliser price coefficients are insignificant. Many farmers did not use fertilisers, especially in Aurepalle. This may obscure possible complementarity or substitutability of labour and fertilisers. The bullock price coefficients indicate that female labour and bullocks were complements in Kanzara: farmers can control weed though manual weeding by women or through interculturing with bullocks. Bullock prices are not significant in the male labour equations. However, the significantly positive sign for the bullock ownership dummy in the Kanzara male labour equation indicates not only that bullock-hiring markets were imperfect in this village, but also that male labour and bullocks were complements. The insignificance of the bullock-ownership dummy in the Aurepalle equations suggests that bullock-hiring markets were rather efficient in this village.

4.4. Implications for employment studies

In order to absorb the increasing population of India's rural SAT, agricultural employment should expand continuously. The development of effective policy measures will benefit from insights into the determinants of labour demand from smallholders, the main agricultural employers. Nevertheless, previous research has failed to account for the effects of possibly the most pervasive characteristics of SAT agriculture: risk and credit constraints. Prior studies, moreover, have neglected a potentially important means to alleviate the consequences of these constraints: family labour. Farm households can use wage income to purchase inputs as well as to reduce the variability of overall household income. Consequently, nonfarm employment programmes may affect employment not only directly, but also indirectly through their impact on agricultural employment. This indirect effect is currently ignored in policy evaluations.

The model presented in Chapter 3 is used to elucidate the potential impact of risk, credit constraints, and family labour on crop labour use. As production and consumption decisions are nonseparable, risk, nonagricultural assets, and household preferences affect the use of labour in crop production. The impact of risk depends on household preferences and is ambiguous: labour may increase or decrease production risk. On the other hand, credit constraints will unambiguously lead to a decrease in labour use. Family labour can mitigate the effects of both risk and credit constraints.

Estimates of labour use in two villages in India's SAT indicate that the impact of short-term production credit constraints was negligible, while risk affected labour use in various ways. First, risk decreased the willingness to borrow and, thus, decreases labour use. Second, risk affected labour use more directly through crop technology. The use of labour will either increase or decrease production risk, depending on the biophysical environment of the farmer and the technology used. The estimates show that farmers adapted labour use accordingly.

The empirical estimates confirm the hypothesis that exogenous employment possibilities affect farm labour use. The effect is twofold. First, the availability of year-round off-farm employment allows households to use family labour for risk management. As a result, there is less need to adapt the use of crop labour to production risk. Depending on crop technology and the biophysical environment, this can imply both an increase and a decrease in the use of labour.

The results have interesting consequences for employment policies. Improving dry-season employment will affect cropping-season labour use. Since the relation between labour income and agricultural employment is ambiguous, it is not possible to draw general conclusions about the direction of the effect. Depending on the specific production environment, dry season employment may either crowd out or stimulate agricultural employment. The actual effects are site- and gender-specific. At any rate, evaluations of public-works programmes that do not account for these effects are likely to be biased.

5. DO PUBLIC WORKS DECREASE FARMERS' SOIL DEGRADATION?

Labour Income and the Use of Fertilisers in India's Semi-Arid Tropics[19]

This chapter focuses on the possibility of using public works to stimulate farmers' fertiliser use in India's SAT. Inadequate replenishment of removed nutrients and organic matter has reduced fertility and increased erosion rates. Fertiliser use, along with other complementary measures, can help reverse this process, which ultimately leads to poverty, hunger, and further environmental degradation. In a high-risk environment like India's SAT, there may be a strong relation between off-farm income and smallholder fertiliser use. Farmers can use the main source of off-farm income, wage income, to manage risk as well as to finance inputs. Consequently, the introduction of public-works programmes in areas with high dry-season unemployment may affect fertiliser use. This study confirms the relevance of risk for decisions regarding fertiliser use in two Indian villages. Nevertheless, governments cannot use employment policies to stimulate fertiliser use. Public works even decreased fertiliser use in the setting of this study.

5.1. Introduction

Sustainability has been an important subject on the political agenda since the 1980s. Many people have realised that we cannot sustain economic development if we do not maintain the services and quality of natural resources over time. Sustainable development, therefore, requires the utilisation of renewable resources at rates less than or equal to the natural rate at which they can regenerate. Moreover, waste flows to the environment should be kept at or below the assimilative capacity of the environment (Pearce and Turner, 1990). Agricultural research and policy in developed countries tends to stress the latter aspect. A major concern is the contamination of surface and groundwater from (in)organic fertilisers and pesticides (Parr *et al.*, 1990). This type of research has limited relevance for the developing world, where the use of chemical inputs is low except in the most productive regions. A sharp degradation of natural resources is the basic challenge to be met in this part of the world (*e.g.* Reardon (1995) for the Sahel; Byringiro and Reardon (1997) for Rwanda; and Randhawa and Abrol (1990) for India).

Although several factors have contributed to soil degradation, inadequate replenishment of removed nutrients and organic matter has reduced fertility and increased

[19] This chapter is a revised version of a paper that will be published in Environment and Development Economics.

erosion rates (Bumb and Baanante, 1996). Between 1954 and 1990, nutrient depletion in India has caused light degradation of 1.9 million hectares of land, moderate degradation of 10.3 million hectares, and severe degradation of 1.5 million hectares (Van Lynden and Oldeman, 1997). Declining soil quality on smallholder fields initiates a process that ultimately leads to poverty, hunger, malnutrition, and further environmental degradation (Pinstrup-Anderson and Pandya-Lorch, 1994).

Fertiliser use, along with other complementary measures, can help reverse the downward spiral of environmental degradation in several ways (Bumb and Baanante, 1996). First, fertiliser can provide much-needed nutrients and hence increase crop yields and food production. Second, higher yields imply more biomass, which helps maintain soil organic matter and vegetative cover. Third, by increasing crop production in high-potential areas, fertiliser use can reduce the pressure to clear forests for crop production. In addition, fertiliser use can help reduce global warming by enhancing sequestration of carbon in soil organic matter.

Despite the country's impressive record of crop production, India's per-hectare use of fertilisers is among the lowest in the world. Overall, less than half of the nutrients removed by crop production were applied as chemical fertilisers in 1983 (Randhawa and Abrol, 1990). Fertiliser use doubled between 1983 and 1999, but this was accompanied by an increase in cereal production of 40%, pulses of 15%, and of other crops of on average 50% (FAO, 1999). Moreover, aggregate numbers obscure strong regional differences. Production growth has come about largely in irrigated agriculture, and the government is increasingly concerned about the exorbitant use of fertilisers in these areas. On the other hand, agriculture has developed little in rain-fed areas. Although 70% of the country's gross cropped area is farmed under rain-fed conditions, dryland agriculture received only 20% of total fertiliser in 1983 (Randhawa and Abrol, 1990). What is more, a significant share of cultivated area does not receive any fertiliser at all. Application of animal manure and atmospheric deposits somewhat reduce the gap between nutrient removal and replenishment resulting from low fertiliser use, but not enough to prevent the depletion of large dryland areas.

The existing nutrient deficits will have an adverse effect on food security and resource conservation unless additional efforts are made to promote higher levels of fertiliser use in an environmentally sound manner (Bumb and Baanante, 1996). In the near future, a significant increase in the use of organic fertilisers is not feasible in India's SAT. Farmers value manure highly, but apply far less than what they view as desirable, as fodder availability limits the number of livestock that farmers can keep. Moreover, biomass scarcity makes the economics of mulching and green manuring in dryland agriculture decidedly unattractive (Walker and Ryan, 1990).

Effective promotion of fertiliser use requires clear insights into the determinants of input use at the farm level. Macroeconomic factors such as trade and exchange rate policy, foreign exchange availability, and inflationary pressures are important, but cannot explain differences in fertiliser application between neighbours or even regions. To explain these, we need to look into the farmers' microeconomic environment. For India's SAT, the major features are the large variability of crop yields, the limited development of (especially long-term) financial markets, and the importance of wage income for smallholder livelihood.

Wage income may have a strong impact on crop production in general and fertiliser use in particular. Households can use wage income to purchase fertilisers if they are unable or unwilling to take production loans (Reardon et al., 1994). Moreover, wage income may help reduce the variance of overall household income and improve food security by allowing the household to buy food in cases of yield shortfalls (Reardon, 1997). Wage income may, therefore, induce households to increase the riskiness (and profitability) of their agricultural activities. Depending on the relation between fertiliser use and production risk, this will lead to either an increase or a decrease in fertiliser use (Hanus and Schoop, 1989).

The above indicates that rural employment policies can lead to changes in smallholder fertiliser use. Village labour markets are reasonably competitive and responsive to the forces of supply and demand (Walker and Ryan, 1990). Nevertheless, in some areas unemployment rates are relatively high during the slack season. Employment policies could stimulate the use of inorganic fertilisers in these areas, provided that wage income increases fertiliser use.

Despite the potential importance of wages and other sources of off-farm income for fertiliser use, few researchers have addressed this topic. Kelly (1988) included off-farm income as an explanatory variable in a regression of farmers' fertiliser use. She found that off-farm income increased fertiliser use, but her results do not shed light on the workings of the underlying decisions and constraints. The model developed in Chapter 3 helps us to unravel the household decision process regarding fertiliser use. Contrary to previous research, the empirical analysis resulting from this model allows a distinction between the effects of risk and credit constraints.

The structure of the chapter is as follows. Section 5.2 elaborates on the problem of soil mining and describes the interaction between risk, credit, and fertiliser use in India's SAT. Section 5.3 examines empirical estimates of the determinants of household-level fertiliser use for the two study villages representing distinct agro-ecological and policy regions in India's SAT. Policy recommendations and conclusions are presented in Section 5.4.

5.2. Fertiliser use in a risky environment

5.2.1. Fertiliser use and sustainability

A recent survey on human-induced soil degradation reports that erosion and depletion of plant nutrients is slowly reducing about 80% of the cultivated land in the SAT to unproductive, parched terrain (Van Lynden and Oldeman, 1997). The magnitude of soil mining in rainfed agriculture is huge. Estimates of average nutrient removal have been as high as 200 kg of nitrogen, 30 kg of phosphorous, and 150 kg of potassium per hectare during the last decade (NRMP, 2000b). In many areas, the situation has reached the point where production gains cannot be achieved without a substantial increase in inputs. Nevertheless, farmers rarely perceive erosion and soil depletion as a high-priority problem. The losses in current productivity are low and can be masked by increased levels of inputs. Still, the losses are alarming in the long run or on a large area basis (Koala, 1999). Counteracting nutrient depletion requires an integrated approach including the use of organic as well as mineral fertilisers.

Out of concern for the limited sustainability of current production systems, ICRISAT has initiated several projects focussing on improved nutrient management. A region that is getting special attention is the Mahbubnagar district, which is representative for rainfall-unassured red soil areas. The district has degraded soils with low fertility, and the main nutrient constraint is nitrogen (NRMP, 2000a). Other regions that are getting special attention are those areas with medium-textured black soils. These areas are prone to severe degradation. The major biophysical constraints to crop production on these soils are soil erosion and depletion of nutrients.

The two study villages represent the attention areas described above: Aurepalle in the Mahbubnagar district represents red-soil areas; while Kanzara in the Akola district represents medium-textured black-soil areas. In both villages, the use of inorganic fertilisers is low but increasing (see Figure 5.1). Fertiliser use was more widespread in Kanzara than in Aurepalle. Especially in the latter village, farmers have applied fertilisers disproportionately to irrigated area. The picture is changing as more and more farmers apply fertilisers on their dryland crops. Nevertheless, some dryland fields remain unfertilised, and the amount of nutrients applied on fertilised fields is low. Tentative nitrogen balances for the major crops and crop mixtures in the two study villages indicate that nutrient removal is at least as high as the SAT averages presented above (see Table 5.1).

Figure 5.1. Spread of fertiliser use in two villages in India's SAT (1975-1984)

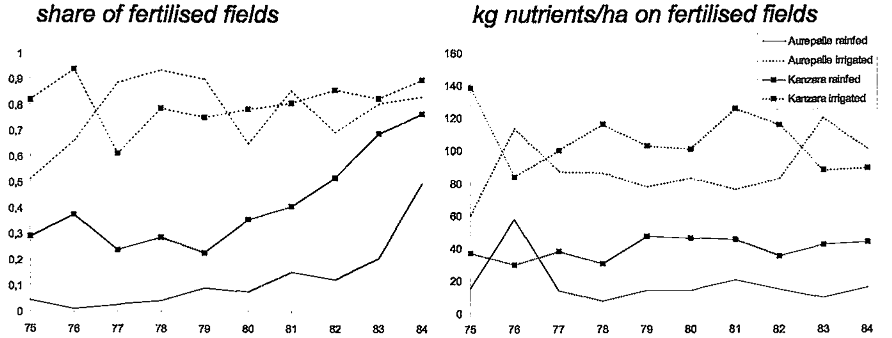

Table 5.1. Tentative nitrogen balances for the study villages (kg/ha)

	Aurepalle		Kanzara	
	sorghum/pearl millet/pigeon pea	castor	hybrid sorghum	cotton/pigeon pea/local sorghum
Nitrogen additions				
manure	0	0	0	0
fertiliser	0	0	15	0
biological N fixation	3	0	0	5
Nitrogen losses				
removal with crop	24	18	63	23
leaching	?	?	?	?
volatilisation	0	0	5	0
Balance	<-21	<-18	<-53	<-18

Sources: Dev (1994); NRMP (2000a); Walker and Ryan (1990)

5.2.2. Fertiliser use in a high risk environment

The results reported in the previous chapters indicate that risk will affect fertiliser use. Inputs affect not only the level of output, but also its variability. Hence, farmers can manage risk through adaptations in input use. Whether this implies that risk leads to an increase or decrease of the use of a specific input depends on the risk characteristics of the input (see section 4.2).

The relation between fertiliser use and the riskiness of crop production is ambiguous and depends on the specific environment, crop, and technology. Some researchers have not found significant effects of fertiliser intensity on yield variability (*e.g.*, Smale et al (1998) and Traxler et al. (1995) for wheat in the Punjab of Pakistan and Mexico, respectively). On the other hand, Hanus (1989) concluded that nitrogen applications at the beginning of growth reduce the variability of wheat and barley yields, while applications at later stages increase yield variability. Besides timing, the type of technology shapes the relation between nitrogen and yield variability, as two studies on Philippine rice cultivation illustrate. In the humid and semi-humid areas of the Philippines, nitrogen is risk-reducing for modern rice varieties under careful management (Antle and Crissman, 1990), but moderately risk-increasing under average technological conditions (Roumasset, 1989). Hence, whether fertiliser increases or decreases yield variability is essentially an empirical matter that may well vary considerably from site to site (Hanus and Schoop, 1989). It is not possible to extrapolate results from the humid and semi-humid tropics to dryer areas, as the frequent occurrence of moisture stress could interact with nitrogen to produce greater yield variability with nitrogen application (Smith and Umali, 1985). The production function estimates presented in Chapter 3 indicate that fertilisers increased risk in both study villages.

Farmers risk perceptions, however, do not necessarily coincide with the technical effect of fertilisers on yield variability. Empirical evidence indicates that fertilisers increase the yield variability of sorghum yields in the USA. Nevertheless, SriRamaratnam *et al* (1987) found that 10 out of 12 Texas sorghum producers considered nitrogen fertiliser to be risk-reducing. Consequently, typical U.S. farmers apply more nitrogen than the profit-maximising level (Babcock, 1992). This is rational if *ex post* optimal fertiliser rates are positively correlated with yield.[20] In this case, fertilising for average conditions leads to relatively high levels of foregone income in good years, while the costs of some additional fertilisers in normal years are relatively low (Babcock and Blackmer, 1994). Uncertainty about the availability of nitrogen in the soil can also explain the observed high levels of nitrogen application. If the marginal product of nitrogen is a convex function, increasing uncertainty about the availability of soil nitrogen will increase nitrogen application. This is true for many functions, such as the Cobb-Douglas and the Mitscherlich production function (Babcock, 1992). The intuition of this result is that increasing nitrogen usage above the amount that is needed on average imposes less loss when soil nitrogen is abundant than the gain when soil nitrogen is deficient.

[20] This condition holds if fertiliser is inexpensive relative to its marginal value in production when less-than-optimal rates are applied.

5.3. Farmers' fertiliser use in the study villages

5.3.1. The empirical model

The model from Chapter 3 can easily be extended to include fertiliser use as an additional input besides labour. The resulting first-order conditions for fertiliser use equal that for labour, but for inclusion of the fertiliser price instead of the wage rate. Analogous to Eq (4.6), the first-order condition for fertiliser use is

$$f_I = \frac{p_i(1+r)}{p}\frac{EU_{C_2}}{E(U_{C_2}g_{Q_1})} + \lambda\frac{p_i}{p\rho E(U_{C_2}g_{Q_1})} - h_I\gamma\frac{E(U_{C_2}g_{Q_1}\varepsilon)}{E(U_{C_2}g_{Q_1})}. \tag{5.1}$$

The rationale for decisions on fertiliser use is thus the same as that for labour use. Credit constraints can prevent farmers from buying the desired amount of fertiliser. The impact of risk is subtler. Farmers with limited options to smooth consumption will try to stabilise income. One way of doing this is adapting fertiliser use to account for the effect of fertilisers on output variability. Depending on the crop technology and the production environment, this may imply either an increase or a decrease in fertiliser intensity compared to a risk-free setting. The effects of both risk and credit constraints can be alleviated through adaptations in family labour supply: labour income provides liquidity and can stabilise total income.

The reduced-form equation for fertiliser use derived from the extended model is

$$\frac{I}{A} = F(A, p, w_1, w_2, p_i, r, \gamma, T_1, T_2, \rho, Z). \tag{5.2}$$

Village-specific fertiliser functions account for the differences between Aurepalle and Kanzara. The estimates use data on the application of the most frequently utilised nutrient: nitrogen. As only some of the farmers apply nitrogen, suitable regression methods are tobit regression and Cragg's model: a combination of probit and truncated regression. The second option was used in the present study, as equality of the effects of the independent variables on the decision to use fertilisers and the quantity of fertilisers used is strongly rejected.

The reported variance estimators are robust for the panel nature of the data: the estimation method does not assume independence of the observations for a single household. However, contrary to the previous estimates in this study, the equations do not cover an individual effect that takes up fixed household characteristics. Several proxies for household preferences and farming skills partly compensate this shortcoming: the age of the household head, caste, the number of literate household members, and the number of household members with secondary education (see Table 5.1).

Table 5.1. Descriptive statistics (1976-1984)

	Aurepalle (N=259)		Kanzara (N=253)	
	mean	standard dev.	mean	standard dev.
Inorganic nitrogen use				
nitrogen intensity (kg/ha)	5.67627	10.5504	12.6299	15.9155
nitrogen for users (kg/ha)	12.1969	12.6512	18.6863	16.1755
% of cases with nitrogen>0	46.5385	49.9762	67.5889	46.8969
Agricultural resources				
cultivated area (ha)	3.28075	2.78028	5.70128	7.07898
irrigated area/total area	0.09885	0.17177	0.03411	0.11303
expected yield (Rs/ha)	1021.72	520.298	1025.50	370.260
inherent riskiness of land (γ)	118.080	50.9130	591.886	373.631
bullock owned (yes=1)	0.60385	0.49000	0.57312	0.49561
Prices				
female planting wage rate (Rs/hr)	0.40786	0.12955	0.44408	0.07794
bullock price (Rs/hr)	1.40207	0.21561	2.19089	0.25969
nitrogen price (Rs/kg)	5.92966	0.52076	6.57985	0.92464
Skills				
farm caste (yes=1)	0.34231	0.47540	0.45850	0.49926
age household head	54.1385	12.5531	44.3004	9.56581
number of literate adults	1.32692	1.99150	2.45455	2.00270
adults with secondary education	0.36539	0.84353	0.60079	1.20297
Household assets				
liquid assets (Rs)	5237.56	8131.29	6328.90	12083.8
owned land (ha)	5.60015	7.27233	5.26660	6.49759
livestock ownership (Rs)	4222.29	4374.70	2091.12	2572.31
Labour endowment				
adults	3.76154	1.61940	4.20949	2.21279

Note: All monetary values are in 1983 prices.

In order to detect nonlinearities in the relation between risk, asset ownership, and fertiliser use, the first regression included interaction terms and quadratic variables. Only the interaction term between risk and liquid assets appeared influential and was retained in the final regression. Moreover, the Kanzara equations and the Aurepalle probit equation include a quadratic term for cultivated area. In the case of the Aurepalle truncated regression, inclusion of such a term only decreased the significance of the effect of cultivated area. As in the previous regressions, Hausman tests could not reject exogeneity of liquid assets. Tests for structural breaks were inconclusive due to the use of maximum likelihood estimation with limited degrees of freedom. However, the estimates for subsamples did not seem to alter the results much.

Table 5.2. Estimates of nitrogen intensity in two villages in India's SAT (1976-1984)

	Aurepalle		Kanzara	
	probit (N=259)	truncated (N=113)	probit (N=253)	truncated (N=164)
Agricultural resources				
cultivated area (ha)	0.86235**	-1.77828**	0.33178**	-3.31873***
	(0.43390)	(0.74799)	(0.13380)	(0.99605)
cultivated area squared	-0.02988*		-0.01173***	0.06917***
	(0.01662)		(0.00445)	(0.02341)
irrigated area/total area	14.3419***	44.5129***	1.37564	17.0638*
	(4.24983)	(14.4854)	(2.05306)	(9.67977)
expected yield (Rs/ha)	-0.00078	-0.00116	0.00062*	0.00757*
	(0.00104)	(0.00431)	(0.00033)	(0.00439)
inherent riskiness of land (γ)	-0.02199	0.11857**	-0.00111	0.02402*
	(0.01733)	(0.04875)	(0.00153)	(0.01377)
bullock owned (yes=1)	0.53122	3.67935	0.11420	-10.8307***
	(0.36503)	(2.51825)	(0.30276)	(3.39499)
Prices[b]				
wage rate (Rs/hr)	-1.36024	87.7600*	-1.67245	-12.1602
	(3.39617)	(50.4360)	(2.96979)	(22.1566)
bullock price (Rs/hr)	-0.33288	-7.70530***	-3.39667***	-8.72447
	(0.85725)	(2.75989)	(0.93294)	(15.5073)
nitrogen price (Rs/kg)	-0.53668	7.04020	0.49790	0.50737
	(0.32851)	(6.32957)	(0.31159)	(2.91637)
Skills				
age household head	0.03257**	-0.18462*	-0.01678	0.33431**
	(0.01411)	(0.09917)	(0.01828)	(0.14187)
number of literate adults	0.29498	1.40525	-0.12154	0.41088
	(0.23299)	(1.10303)	(0.15166)	(1.38868)
adults with secondary education	-0.55973*	-1.89711**	-0.04125	-0.75124
	(0.31833)	(0.85945)	(0.27597)	(1.16522)
farm caste (yes=1)	1.11164*	0.93046	1.01559***	7.74202**
	(0.62841)	(3.74715)	(0.25770)	(3.63850)
Household assets				
liquid assets (1000 Rs)	-0.25157*	0.49149**	-0.28066***	0.78501*
	(0.14086)	(0.24553)	(0.08529)	(0.47525)
liquid assets (1000 Rs) × riskiness	0.00245**	-0.00280**	0.00063***	-0.00052*
	(0.00111)	(0.00113)	(0.00017)	(0.00031)
owned land (ha)	-0.10620**	0.04493	0.04467	0.16257
	(0.04836)	(0.11147)	(0.06052)	(0.32911)
livestock ownership (1000 Rs)	0.01354	0.37659**	-0.06516	1.19860
	(0.03998)	(0.16732)	(0.23216)	(0.85467)
Labour endowment				
adults	-0.18034	-0.60144	-0.02039	-1.69336**
	(0.15133)	(0.92720)	(0.09473)	(0.83889)
year	0.28003	-4.66122	-0.05872	3.03234*
	(0.18871)	(2.94492)	(0.09334)	(1.70389)
constant	-24.2678*	361.702	10.1557	-232.216
	(12.8922)	(255.780)	(7.99705)	(153.220)
σ		5.30917***		10.56809***
		(0.58813)		(1.255846)
Wald χ^2	203.97	28753.20	247.99	559.39
Pseudo R^2	0.62		0.38	

Notes: [a] Standard errors are in parentheses. Standard errors are robust for within-household dependence of observations.
[b] Previous year's output prices for the major crops are included in the regression but not in the table: paddy and castor in Aurepalle, cotton in Kanzara, pigeon pea and sorghum in both villages.
[c] Equality of the coefficients for men and women was not rejected at the 5% level.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

5.3.2. Results

The estimates give a clear impression of the effects of risk, short-term credit constraints, and family labour on the use of fertilisers in the two study villages (see Table 5.2). Risk strongly affected the use of fertiliser, while the impact of credit constraints appeared to be negligible. Despite the importance of risk for fertiliser use and the potential use of family labour to manage risk, increased fertiliser use is not a by-product of policies enhancing employment. On the contrary, a decrease in unemployment would even have lead to a decrease in fertiliser use. The rest of this section elaborates on these and other results of the regression.

Farmers in both villages increased the amount of nitrogen applied in response to risk. This contradicts the technical relation apparent from the variance function: fertiliser use increased the variance of output. However, the behaviour of the households coincides with the behaviour of US farmers described in Section 5.2. These farmers perceived fertilisers as risk-decreasing inputs, while in fact fertilisers increased output variability. The effect of risk on nitrogen levels was highest in the high-risk village of Aurepalle, where fertiliser use was least widespread: the risk elasticity of nitrogen intensity was 0.7 for Kanzara and 1.2 for Aurepalle.[21] Risk did not directly affect the probability of nitrogen use.

The asset coefficients reveal that risk was more important than short-term credit constraints were for fertiliser use. This coincides with the findings for labour use presented in Chapter 4. In Aurepalle, larger landowners were less likely to use fertilisers as they had more alternatives to stabilise consumption. The coefficient for land ownership is not significant in Kanzara. Inter-village differences in the availability of long-term credit may explain this difference. In Aurepalle, households increased borrowing in low-income years. Large landowners have more collateral and can borrow more. Kanzara farmers had much less access to consumption-smoothing credit.

Liquid assets increased the use of risk-decreasing fertilisers, just like they decreased the use of stabilising male labour in Kanzara. This reflects prudence: households preferred spending their own funds to taking a loan, which they must repay even when yields are low. The positive effect of liquid assets decreased at high levels of risk. On the other hand, the impact of liquid assets on the probability of fertiliser use was negative because of the importance of liquid assets for consumption smoothing. This effect also decreased with the level of risk.

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[21] These elasticities are computed at village means for fertiliser users.

Farm households with more family members used significantly less fertiliser in Kanzara. This finding confirms the important role of family labour in risk management. Households were less inclined to adapt fertiliser use to manage risk if they could use their labour endowment to cope with production risk. This result confirms the findings reported in Chapters 3 and 4. These indicate that farm households in Kanzara could use family labour to compensate negative shocks in crop income at least partly. Aurepalle households could not do this. They could only increase labour supply in anticipation of risk. Because of the relatively large stabilising impact of family labour in Kanzara, labour-rich households felt less need to use male labour to stabilise crop production in this village. In Aurepalle, the family labour endowment did not affect the use of labour in crop production. The current results indicate that a very similar story holds for the use of fertilisers.

The remaining results do not directly relate to risk and liquidity constraints, but present other interesting insights into the determinants of fertiliser use. Manure and inorganic nitrogen were complements: livestock ownership increased fertiliser use in Aurepalle. Input prices had only a limited impact on fertiliser use. Own-price elasticity is not significantly different from zero in any of the equations, while wage-elasticity is only significant in the level equation for Aurepalle. This significantly positive wage elasticity indicates that labour and fertilisers were substitutes. The price elasticities for bullocks were negative, although they are only significant in the level equation for Aurepalle and the probability equation for Kanzara. These negative bullock price elasticities indicate that animal traction and inorganic nitrogen were complements: crops benefit more from fertilisers in well-worked soil. In this light, the negative coefficient for bullock ownership in Kanzara is puzzling.

The estimates confirm the presence of an exogenous positive time trend in the level of nitrogen use in Kanzara. Both the probability of fertilisation and the level of nitrogen increased in Kanzara. Surprisingly, the regressions do not pick up the strong upward trend in the probability of fertiliser use in Aurepalle that seems apparent from Figure 5.1: the time trend in this specific equation is positive, but only significant at the 15% level or higher. Furthermore, the probability of fertiliser use increased with cultivated area, while the nitrogen intensity decreased with area size in both villages. These effects levelled off for very large farms.

As expected, irrigation was an important determinant of fertiliser use. The irrigation coefficients are significantly positive in all equations, except the probability equation for Kanzara. These results are in line with the observation that, in both villages, irrigated area has laid claim to a relatively large share of fertilisers, but that in Kanzara, dryland crops also received an appreciable amount. In the latter village, fertiliser use was higher on soils with a higher expected yield. This effect was dominated by the irrigation effect in Aurepalle.

Finally, household skills had a significant impact on fertiliser use. The age of the household head increased the level of nitrogen used in Kanzara and the probability of nitrogen use in Aurepalle. Nevertheless, in the latter village, older farmers applied smaller quantities of nitrogen than their younger colleagues did. Their experience induced them to use fertilisers, but only in small quantities. The farm caste dummy also reflects the importance of farming skills for fertiliser use. Households from traditional farming castes were more likely to use fertilisers and apply larger quantities. Literacy did not affect fertiliser use, while secondary education decreases both the probability and the level of nitrogen applications in Aurepalle. Apparently, highly educated families did not put a high value on agriculture.

5.4. Conclusion and policy implications

Fertilisers are important inputs in smallholder production in India's SAT. Not only do they affect crop yields and profits, they also have a strong impact on the future production capacity of dryland soils. Currently, nutrient balances are strongly negative, and special efforts are required to maintain soil productivity. As the potential for organic fertilisation is limited, restoring nutrient balances involves a significant increase in fertiliser use. In order to design effective policy measures for achieving this goal, governments need a profound insight into the determinants of smallholder fertiliser use.

The analysis for fertiliser use runs parallel to the analysis of labour supply in the previous chapter. The theoretical grounds for the use of all variable inputs are identical. This implies that credit constraints will decrease the use of fertilisers, while the effect of production risk is ambiguous. Family labour mitigates the impact of both risk and credit constraints.

Estimates for the study villages reveal that risk strongly affected fertiliser use: output variability increased the use of fertilisers in both villages. This implies that the village households utilised fertilisers to decrease risk, which coincides with the behaviour of U.S. farmers. The effects of the farmers' asset endowment on fertiliser use confirm this observation: wealthier households, which were better able to smooth consumption, used less inorganic nitrogen. On the other hand, constraints on short-term credit did not limit fertiliser use. This corresponds with the findings for labour use described in Chapter 4.

A starting-point of this research was the notion that employment policies might affect fertiliser use. The model suggests that off-farm employment decreases the effect of risk on fertiliser use and thus leads to a lower use of fertilisers. This implies that the introduction of public works or self-employment programmes in areas with high levels of dry-season unemployment would diminish fertiliser use. The regressions confirm this effect: fertiliser use decreased in reaction to improved off-farm employment opportunities as measured by the family labour endowment. In other words, dry-season employment programmes, although valuable in their own right, cannot be used to promote smallholder fertiliser use.[22]

The empirical estimates suggest another interesting, although not very surprising, direction for policy. In the study period, lack of knowledge has limited fertiliser use. Older farmers from traditional farming families used more fertilisers than their fellow villagers did. The greater familiarity of farmers with modern inputs in later years explains probably at least part of the positive time trend for nitrogen use. Given that India's fertiliser use was still low by the end of the 1990s, it nevertheless seems justified to conclude that extension is even now a suitable method to stimulate fertiliser application. Extension is a more effective method than (changes in) price subsidies: the nitrogen price did not significantly affect the nitrogen use during the survey period.

[22] On the other hand, stimulating off-farm employment could help decrease nutrient pollution in high-production areas. To test this assertion, more information on the specific production environment and household behaviour in these areas is needed.

6. FARM-HOUSEHOLD INCOME IN A RISKY ENVIRONMENT:
The Role of the Labour Market in India's Semi-Arid Tropics

A simple two-stage simulation model based on the analytical model and the regression results from Chapters 3 to 5 is presented in this chapter. The simulation model consists of a production function, an income equation, and reduced form equations for the use of all major inputs and household labour supply. The results indicate that the risk-management strategies presented in Chapter 3 — ex ante risk management and ex post income smoothing through family labour supply — were effective in increasing the minimum income of the survey households. Much more important for income stability was, however, the flow of labour income that households earned independent of their risk preferences. The simulations also reveal that the impact of production risk on household income through changes in input use was small. Finally, harvest-wage variability due to yield covariance had little effect on household behaviour.

6.1. Introduction

Several interesting findings regarding the relation between family labour and crop input use in a risky environment were presented in the previous chapters. These chapters show that farm households in two villages in India's SAT use family labour as well as crop inputs to manage income variability. However, what was the quantitative importance of the various risk management strategies for the level and stability of household income? The previous chapters likewise did not deal with the potential covariance of yield shocks and the resulting household reactions regarding labour supply and demand in the harvest-stage. To what extent did yield covariance hinder harvest-stage risk coping? Before explaining the approach followed to address these unresolved issues, this introduction will first go somewhat deeper into the research questions suggested by the results from Chapters 3-5.

It was shown in Chapter 3 that the farm households studied used labour markets to manage income risk. Small and medium farmers in Kanzara compensated, on average, 21% of unexpected losses in crop income through increases in the family supply of harvest labour. In Aurepalle, this number was a negligible 4%. There, farmers increased family-labour supply during the planting stage in response to risk. Besides, the very presence of a secure labour income decreased the chance of very low incomes in both villages. These observations leave us with two questions: What was the quantitative effect of this *ex ante* behaviour on the intertemporal distribution of income? And how important was the stable flow of labour income for decreasing the coefficient of variation (CV) of household income?

Chapters 4 and 5 revealed that risk affected the use of variable inputs in crop production and that labour income could reduce these effects. Farmers believed that the use of inorganic nitrogen decreased yield risk. An increase in production risk, therefore, led to an increase in fertiliser use. A similar, but somewhat more complicated story can be told for the use of crop labour. In Aurepalle, farm households considered both male and female labour as risk-increasing inputs. Consequently, production risk led to a decrease in the use of both types of labour. On the other hand, Kanzara farmers considered male labour as risk-decreasing and female labour as risk-neutral. They, therefore, increased the use of male labour in response to an increase in production risk. The presence of able-bodied family members decreased the effects of risk on input use in Kanzara. Kanzara households could stabilise income *ex post* by increasing family-labour supply after a bad harvest. This decreased the need to use crop inputs to manage risk *ex ante*. Aurepalle households had only limited possibilities to use family labour for *ex post* income smoothing. Hence, in this village, the household labour endowment did not affect input use. Chapters 4 and 5 considered the implications of these interactions between risk, input use, and family labour for labour market policies and sustainability. But how large was the effect of risk-induced changes in input use on household income?

Finally, Chapters 3-5 considered the response of individual households to production risk. Individual responses are, however, likely to interact at the aggregate level (Barnum, 1979). In the study setting, this interaction could have resulted in riskiness of the harvest-wage rate. Consider a village with an insulated labour market like the study villages. Now suppose that this village experiences a dry spell causing large yield losses for all village farmers. These low yields are associated not only with a low demand for harvest labour, but also with a high supply of family labour: households will try to compensate the loss of crop income by offering their labour in the market. Hence, wage rates will dramatically decrease or, if wage rates are downward sticky, unemployment rates will rise substantially. In other words, covariate yield shocks will inhibit the use of labour markets for *ex post* income smoothing. The model used in the previous chapters ignores this possibility. The question is to what extent did covariate yield shocks limit the usefulness of labour markets for income smoothing in the two study villages?

In the present chapter, a simple simulation model based on the results from the previous chapters is presented to answer the above questions. The structure of the chapter is as follows. Section 6.2 describes the simulation model, while section 6.3 presents the results from base-run simulations and from simulations of changes in risk and family labour. Section 6.4 addresses the issue of stochastic harvest wage rates. Conclusions are presented in Section 6.5.

6.2. Simulation of household behaviour

A simple simulation model based on the regression functions from the previous chapters is presented in this section. Central to the model is the uncertainty of crop yields in the planting stage. In the planting stage, the household decides on the level of labour supply and input use given resource endowments, preferences, prevailing prices, and the inherent riskiness of land. The inputs are used in an agricultural production process that is modified by a stochastic shock. The result of this process is the standing crop at the beginning of the harvest stage. Given this crop, the household subsequently decides on the amount of harvest labour to be used and the number of hours to be worked during the harvest stage. The final result of this decision process is total household income and total family labour supply. Both are stochastic, as they are affected by a random yield shock.

Central to the model is a stochastic production function (see (Eq (3.1)). This function includes a random shock with mean 0 and standard deviation 1. In order to get a clear impression of the impact of such a shock, a random series of 1000 shocks with distribution $N(0,1)$ was generated. Each shock is associated with a certain level of production, income, and labour supply. Combined, these outcomes present the effect of yield risk on household income. As the model does not include a utility function, it cannot be used to do a welfare analysis of household behaviour. The reduced form equations, however, represent actual household responses to exogenous changes. Hence, the simulation results are indicative of the importance of risk and family labour for crop production and household income in the study villages.

The previous chapters provide several important components of the simulation model: the production function (Chapter 3), labour supply functions (Chapter 3), and functions for the use of three major crop inputs: male and female planting labour (Chapter 4) and inorganic nitrogen (Chapter 5). Besides these functions, the simulation model includes an equation specifying household income as a function of crop production, input use, labour supply, wage rates, and prices. Finally, the model comprises functions for two remaining crop inputs: bullock traction and harvest labour. The sections below present the estimates for the latter functions.

6.2.1. Animal traction

Table 6.1 presents estimates for the use of bullock traction in the two study villages. The independent variables equal the variables in the labour and fertiliser use equations, which are presented in section 4.3.1. As joint insignificance of all consumption-related variables could not be rejected for Aurepalle, the function for this village is estimated including production characteristics and prices only. Two-stage least-squares regression was used to account for the endogeneity of cultivated area in the Kanzara equation. The current section discusses only the second stage of the regression. The results of the first stage are presented in Appendix 3.

Bullock ownership had a significant positive effect on the use of oxen traction in Kanzara. This confirms the conjecture from Chapter 2 that the seasonality of production may have inhibited the full development of a rental market for bullocks. The absence of an effect of bullock ownership on the use of oxen in Aurepalle, however, indicates that the traction market worked quite smoothly in this village. These results are in line with with the findings from Chapters 4 and 5: bullock ownership increased the use of male labour and fertilisers in Kanzara, but did not affect input use in Aurepalle.

In both villages, bullock intensity decreased with farm size. Kanzara farmers utilised more traction on soils with low expected yields, while there was no significant effect of land quality on the use of animal traction in Aurepalle. Given expected yields, irrigation did not affect bullock use in either village. The bullock intensity increased over time in Kanzara, while it was constant in Aurepalle.

The own-price elasticity of bullock use was significantly negative in both villages. Nitrogen prices did not affect bullock use. The wage elasticity was significantly positive in Kanzara. This indicates that animal traction and labour were substitutes in this village. On the other hand, wage rates did not significantly affect the use of bullock traction in Aurepalle. There were two separate relations between labour and traction. Firstly, male labour and animal traction were complements. Secondly, hand weeding by women and interculturing by oxen were substitutes. The joint effect differed between the two villages.

Production risk did not affect bullock use in either village. In line with this behaviour, the proxies for the household capacity to manage risk —illiquid asset holdings and family labour— did not affect bullock use. Nevertheless, Kanzara farmers holding greater stocks of liquid assets used more animal traction. The same was observed for male labour and inorganic nitrogen: farmers were prudent and preferred using their own money to borrowed money.

Table 6.1. Fixed effect estimates of ln(bullock hrs/ha) (1976-1984)

	Aurepalle[a] (N=254)	Kanzara (N=247)
Agricultural Resources		
ln(cultivated area)[b]	-0.11203***	-0.41079*
	(0.04059)	(0.21259)
irrigated area/total area	0.35484	-0.15425
	(0.24428)	(0.20703)
ln(expected yield)	0.08776	-0.21424*
	(0.11328)	(0.12075)
ln(riskiness land (γ))		-0.03126
		(0.13121)
Bullock owned (yes=1)	-0.02955	0.35610***
	(0.05792)	(0.10613)
Prices		
ln(wage rate)	-0.24838	1.60397***
	(0.70633)	(0.5186)
ln(bullock price)	-0.82059*	-0.69704*
	(0.46272)	(0.38737)
ln(nitrogen price)	0.49141	0.06078
	(0.38600)	(0.24484)
Assets		
ln(liquid assets)		0.08165***
		(0.03023)
ln(land owned)		0.00990
		(0.16943)
ln(livestock)		0.00602
		(0.02034)
Labour endowment		
ln(adults)		0.01700
		(0.08939)
year	0.02595	0.03711*
	(0.09872)	(0.02038)
Adjusted R^2	0.67	0.45

Notes: [a] Profit maximisation could not be rejected at the 10% level.
[b] Ln(previous-year cultivated area) was used as an instrument for this variable in the Kanzara equation. (See Appendix 3.)
All monetary values are in 1983 prices.
Previous-year village-level prices for pigeon pea, sorghum, cotton (only Kanzara), paddy and castor (only Aurepalle) were included in the regression but not in the table.
Standard errors are in parentheses.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively

6.2.2. Harvest-stage labour use

The analytical model presented in Chapter 3 predicts that production and consumption decisions are separable in the harvest stage. Consequently, profit maximisation and not household utility maximisation drives harvest-labour use. This assumption was tested by estimating an extended harvest-labour function including variables related to profit maximisation — the value of output, output prices, and the wage rate — as well as utility maximisation — labour endowment and asset ownership. F-tests for the joint significance of the latter variables indicate that the assumption of separability is justified: labour endowment and asset ownership were jointly insignificant at the 10% level. This conclusion may come as a surprise for the village of Aurepalle, where the flexibility of harvest-stage labour supply was limited. However, it confirms the hypothesis that this limited flexibility resulted from high unemployment rates during the dry season and not from labour market imperfections during actual harvesting.

Following the above results, the ultimate reduced form labour-use function assumes profit maximisation (see Table 6.2). Two-stage least squares was used to cope with the endogeneity of output value (see Appendix 3 for the first-stage estimates.) The explanatory power of both functions is over 90%. The output elasticity of harvest labour was 1.00 in Kanzara and 0.75 in Aurepalle. As expected, the wage elasticities were negative for both villages: -0.92 and -0.53 in Aurepalle and Kanzara, respectively. Comparing these numbers, we see that Aurepalle farmers were relatively responsive to changes in wage rates, while Kanzara farmers accounted most strongly for changes in output. A shift in cropping pattern may have caused the time trends observed.

Table 6.2. Fixed effect estimates of ln(harvest labour hrs) (1976-1984)

	Aurepalle (N=262)	Kanzara (N=271).
ln(output value)[a]	0.75232***	0.99554***
	(0.09152)	(0.06343)
ln(wage rate)	-0.91659***	-0.52781**
	(0.14365)	(0.20520)
year	0.06679***	-0.02229*
	(0.01963)	(0.01171)
Adjusted R^2	0.87	0.92

Notes: [a] Instruments are used for this variable (see Appendix 3 for the first-stage estimates)
All monetary values are in 1983 prices.
Previous-year village-level prices for pigeon pea, sorghum, cotton (only Kanzara), paddy (only Aurepalle), and castor (only Aurepalle) were included in the regression but not in the table.
Standard errors are in parentheses
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively

Recall that equality of planting and harvest production was imposed to estimate the production function in Chapter 3. The estimates presented in Table 6.2 indicate that this assumption is not fully correct. Farmers did not simply harvest a given crop, but decided on the amount of harvest labour to use based on the state of the crop *and* harvest wage rates. However, the effect that this decision had on harvested output is not likely to be very large.

6.2. Farm-household labour supply and income in a risky environment

6.3.1. The representative households

Three representative farm households were defined for each village. These households are loosely called farmers in the remainder of this chapter. As the main concern of the study is the relation between crop production and family labour, the most logical clustering of village households starts from the size of the area under cultivation. Following previous research (Walker and Ryan, 1990), the households are divided into three farm-size groups that represent equal shares of the village population (see Table 2.2). For each group, the median values for the exogenous variables in the regression functions define a representative household (see Table 6.3 and Appendix 4).

Table 6.3. The representative households

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
Agricultural resources						
cultivated area (ha)	0.8	2.3	5	1.2	3	8
share of irrigation (%)	0	0	20	0	0	0
expected yield (Rs/ha)				1595	1974	1755
inherent riskiness (γ)	72	99	158	330	510	830
ex ante CV of yield	639	703	1056			
bullock owned	no	yes	yes	no	yes	yes
Asset ownership						
liquid assets (Rs)	938	2061	3138	692	1137	7000
land (ha)	0.9	2.6	7.5	1.3	2.5	9
livestock (Rs)	1230	2142	5405	378	848	3500
Labour endowment						
men	2	2	2	2	2	2
women	2	2	2	2	2	2
Skills						
farm caste	no	no	yes	no	yes	no
age	52	52	52	45	45	45
literate adults	0	0	2	1	1	4
adults with sec. education	0	0	0	0	0	1

The only exception is the group of large farmers in Kanzara. The median size of cultivated area for this group is 10 hectares. These very large farms are, however, not of interest for the current study: Chapter 3 reveals that Kanzara farmers cultivating over 8 hectares of land do not use family labour for risk management. Hence, the representative large-farm household in Kanzara cultivates only 8 hectares. The other exogenous variables are adapted accordingly.

There are striking differences between the six farm households. The Kanzara representative farms are bigger than the corresponding Aurepalle farms. Moreover, the productivity of the black Kanzara soils is much higher than that of the red Aurepalle soils. While expected yields are relatively uniform between the Kanzara three farmers, there are large differences in yield expectations in Aurepalle. The large farmer has relatively high yield expectations because part of his land is irrigated. On the other hand, expected yields are low for the small farmer. Recall that the production function includes a small farmer dummy to account for the low yields observed for small farmers.

Gamma increases with farm size and is much higher for Kanzara farmers than for Aurepalle farmers. This does not mean that risk is lower in Aurepalle. Gamma covers only the exogenous part of output variance. Total variance is just slightly lower in Aurepalle than in Kanzara, and coefficients of variation computed from the production function are highest for Aurepalle.

Asset ownership increases with cultivated area in both villages. Land ownership is lowest for the small farmer in Aurepalle and highest for the large farmer in Kanzara. The two medium farmers own similar amounts of land. Aurepalle farmers own more livestock than Kanzara farmers from the same farm-size class. The inter-village division of liquid assets is complex. The Kanzara large farmer owns by far the most liquid assets, while for the other farmsize groups, liquid asset ownership is highest in Aurepalle. Bullock ownership is confined to the representative medium and large farmers in both villages.

The availability of family labour does not differ between villages and farm sizes: all representative households are defined to consist of two men and two women. As children do not affect the simulations, the representative households are made up of adults alone. Education increases with farm size and is more widespread in Kanzara than in Aurepalle. In Aurepalle, the representative large farmer belongs to a traditional farm caste, while in Kanzara this farmer originates from a family of landowners, and the medium farmer is the one from the farm caste.

6.3.2. Base-run scenario

Substituting the characteristics of the representative households in the regression functions is not sufficient to obtain base-run estimates of input use and labour supply. Most decision functions are estimated using fixed-effects regression. Hence, the simulation model requires the inclusion of fixed effects for each reference household and each relevant function. The fixed effects included are such that the outcome of each function approaches the median for the observed value in the respective farmsize group.[23] This led to fixed effects that lie within the range of estimated values for all equations.

Table 6.4 presents the results of the base-run simulation. Crop production was restricted to be positive, while minimum harvest labour supply was set at two hours per cultivated hectare. The latter is only relevant for the large farmers. Mean values and SDs and CVs summarise the effect of the stochastic shock. There are clear differences in behaviour between the villages and the households. Differences in input use and labour supply result from differences in fixed effects and for reasons explained in the previous chapters. Nevertheless, some points are worth stressing.

Table 6.4. Crop production, income, and labour supply

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
Input use						
male labour (hrs/ha)	88	106	116	122	128	124
female labour (hrs/ha)	15	21	85	155	151	125
inorganic nitrogen (kg/ha)	0	0	6	0	17	4
bullock traction (hrs/ha)	85	96	111	61	79	93
Crop output						
mean output (Rs)	552	1752	7164	1140	5397	12353
mean yield (Rs/ha)	682	762	1433	942	1799	1544
SD output	368	818	2840	651	1938	3098
CV of output	67	47	40	57	36	25
Crop income						
mean crop income (Rs)	387	1418	5736	578	4099	9654
% crop income to total	28	65	90	17	62	87
SD crop income	325	738	2580	506	1726	2725
CV crop income	84	52	45	88	42	28
Labour supply						
mean labour supply (hrs)	2130	1655	1332	3596	3344	1917
mean labour supply per capita	533	414	333	899	836	479
SD labour supply	25	58	201	177	602	771
CV labour supply	1	3	15	5	18	40
Total income						
mean total income (Rs)	1385	2189	6338	3328	6621	11054
mean total income per capita	346	547	1585	832	1655	2764
SD total income	312	710	2483	359	1224	2122
CV total income	23	32	39	11	18	19

The CV of output decreases with farm-size in both villages and is highest in the rainfall-unassured village of Aurepalle. Kanzara farmers obtain relatively high yields due to

[23] I considered the median values for input use per hectare and labour supply per adult.

the high productivity of their soils and the corresponding high input intensity. The yield differences between the three Kanzara farmers are mostly the result of differences in fertiliser use. Both the medium and the large farmer use fertilisers. The medium farmer applies a relatively high dosage of inorganic nitrogen. He belongs to a traditional farm caste, and members of these castes use more fertilisers than their fellow villagers do (see section 5.3.2). In Aurepalle, the yield differences follow the yield expectations presented in Table 6.3. Yields are especially high for the large farmer, who not only has irrigation but also uses fertilisers and relatively high amounts of the other inputs.

The various coefficients of variation expose the stabilising effect of family labour: the CVs of total income, *i.e.*, crop income plus labour income, are much smaller than the CVs of crop income alone. The effect is largest for the small farmers, as these have a relatively high share of labour income in total income. The stabilising effect of labour income is smallest for the Aurepalle large farmer. Labour income is only a small part of his total income, and he has a limited capacity to increase his family labour supply when yields are low (see Chapter 3).

Table 6.5 quantifies the relative importance of the three stabilising effects of labour income: i) the presence of a stable flow of income; ii) *ex ante* risk management through labour supply, which is relevant in only Aurepalle; iii) *ex post* income smoothing through adapting labour supply to actual crop production. Both the stable stock of income and labour supply for ex *ante* risk management affect only the level of income and not the income variability. In theory, the opposite holds for ex *post* income smoothing. Nevertheless, *ex post* smoothing increases average income for the Kanzara large farmer. This is the result of the minimum set on harvest labour supply: in very good years, the household cannot decrease labour supply any further.

The presence of a stable flow of labour income explains most of the difference between the level and CV of crop income and of total income in both villages. The CV of crop income plus non-risk related labour income is 70% and 83% percent lower than the CV of crop income alone for the Aurepalle and the Kanzara small farmer, respectively. These numbers are lower but still substantial for the larger farmers: 30% and 7% for the Aurepalle medium and large farmer; and 38% and 11% for the Kanzara medium and large farmer. Moreover, the stable flow of labour income secures positive incomes in all years for the small and medium farmers and greatly decreases the maximum loss for the large farmers. Nevertheless, the use of family labour for risk management is certainly not ineffective.

Kanzara farmers use family labour for *ex post* income smoothing only. These farmers compensate 21% of crop income losses through *ex post* income smoothing (see Chapter 3).

Hence, ex *post* income smoothing significantly increases minimum income for all three farmers. The absolute as well as relative increase is highest for the large farmer. His minimum income increases from a loss of Rs 158 to a gain of Rs 3078. The increase in minimum income is 87% for the medium farmer and 12% for the small farmer. Besides, *ex post* smoothing substantially decreases the CV of income of all three farmers. The decrease in the income CV is 29% for the small and medium farmer and 23% for the large farmer. In other words, *ex post* income smoothing through family labour supply considerably decreases income variability in general and the occurrence of very low incomes in particular.

Table 6.5. The effect of labour income on income stability

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
Crop income						
mean crop income	387	1418	5736	578	4099	9654
SD crop income	325	738	2580	506	1726	2725
CV crop income	84	52	45	88	42	28
minimum crop income	-129	-138	-613	-371	-861	-1460
No risk management						
mean total family-labour supply	1868	1295	748	3596	3344	1799
mean total income	1274	2036	6195	3328	6621	10956
SD total income	325	738	2580	506	1726	2725
CV total income	25	36	42	15	26	25
minimum total income	758	480	-154	2379	1661	-158
Only ex ante risk management						
mean total family-labour supply	2130	1655	1332	The households only use family labour for *ex post* risk coping		
mean total income	1385	2189	6338			
SD total income	325	738	2580			
CV total income	23	34	41			
minimum total income	869	632	-10			
Only ex post risk coping						
mean total family-labour supply	1868	1295	748	3596	3344	1917
mean total income	1274	2036	6195	3328	6621	11054
SD total income	313	710	2484	359	1224	2122
CV total income	25	35	40	11	18	19
minimum total income	777	539	86	2656	3105	3078
Ex ante and ex post risk management						
mean total family-labour supply	2130	1655	1332	The households only use family labour for *ex post* risk coping		
mean total income	1385	2189	6338			
SD total income	312	710	2483			
CV total income	23	32	39			
minimum total income	888	691	229			

Aurepalle farmers compensate a mere 4% of crop income losses through *ex post* income smoothing (see Chapter 3). Nevertheless, this behaviour significantly increases minimum income for the two larger farmers. The percentage increases in minimum income are 3% and 13% for the small and medium farmer, respectively. The large farmer increases his minimum income from –154 Rs to 86 Rs. These higher worst-case incomes hardly translate into lower CVs of income.

Aurepalle farmers use family labour not only for *ex post* risk coping, but also for *ex ante* risk management. This strategy has the greatest impact on the income of the medium farmer. *Ex ante* risk management through the labour market increases his minimum income by 32% and his average income by 8%. The small farmer increases his mean income by about the same share (9%), but he increases in minimum income by only 13%. The large farmer increases his mean income by 2% and cuts his maximum losses by 94%. However, this cut is small compared to average income.

6.3.3. Increased production risk

Table 6.6 presents the results of a 10% increase in the inherent riskiness of land. The simulations account only for changes in those choice variables for which the risk coefficient is significant in the reduced form equation. The inherent riskiness is a function of size of cultivated area, land quality, and weather expectations and is thus exogenous to the farmer (see section 3.3.1). In reaction to the increase in exogenous risk, the farmers will change the amount of inputs used in production and the amount of labour supplied by the family. This will lead to changes in both the mean and standard deviation of crop production, household income, and family labour supply.

Kanzara farmers respond to a rise in risk by increasing the use of male labour and fertilisers. They consider these inputs to be risk-decreasing. However, the production function estimates (Table 3.1) show that both inputs increase the variability of output, although the effect of male labour is negligible. Hence, the standard deviation of crop output increases slightly more than the increase in exogenous risk. The higher the increase in fertiliser use, the higher the increase in output variability.[24]

The increased input use leads to a small increase in output. As the value of this increase is higher than the additional costs incurred, an increase in exogenous risk leads to a small increase in crop income. The opposite was expected, as farmers supposedly apply additional inputs to stabilise output at the cost of profits. That this is not the case points at the underutilisation of inputs. We must, however, be careful with this conclusion as the changes in crop income resulting from changes in exogenous risk are very small.

[24] The risk elasticity for fertiliser use is much higher for the Kanzara large farmer than for the Kanzara medium farmer. There are two explanations: i) the large farmer's initial amount of fertiliser is smaller; ii) the large farmer's absolute increase in risk is higher.

Table 6.6. The impact of a 10% increase in the inherent riskiness of land (% increase)

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
Input use						
male labour	-9.8	-9.8	-9.8	7.2	7.2	7.2
female labour	-10.9	-10.9	-10.9	0.0	0.0	0.0
Inorganic nitrogen	-	-	29.3	-	6.1	36.1
bullock traction	0.0	0.0	0.0	0.0	0.0	0.0
Crop output						
mean output	-1.9	-1.9	-1.2	0.7	1.0	2.0
SD output	9.6	9.6	10.6	10.0	10.2	11.4
CV output	11.7	11.7	11.9	9.2	9.2	9.2
Crop income						
mean crop income	0.1	-0.7	-1.3	0.6	0.2	1.0
SD crop income	7.4	8.4	10.0	8.7	10.0	11.2
CV crop income	7.3	9.2	11.5	8.1	9.7	10.1
Total family-labour supply						
mean labour supply	1.2	2.2	4.8	0.0	-0.1	0.3
SD labour supply	7.4	8.4	9.8	8.7	9.8	7.4
CV labour supply	6.1	6.0	4.7	8.7	9.9	7.1
Total income						
mean income	0.8	0.2	-0.8	0.1	0.1	0.9
SD income	7.4	8.4	10.1	8.7	10.0	12.7
CV income	6.5	8.1	10.9	8.6	9.9	11.7

The increase in exogenous risk leads to a rise in the variability of crop income. The magnitude of this rise varies depending on fertiliser use. For the small farmer who does not use fertilisers, crop income variability increases somewhat less than the 10% increase in exogenous risk. At the other extreme, the variability of crop income increases slightly more than exogenous risk for the large farmer, who largely increases the use of risk-increasing fertilisers. Nevertheless, the simulated differences between the exogenous increase in risk and the increase in crop-income variability are small. This implies that adapting the level of input use in response to risk leads to neither a large increase nor a large decrease of income risk.

The second reaction of Kanzara farmers to an increase in exogenous production risk involves an increase in the variability of family labour supply. If crop income turns out to be low, they increase harvest labour supply and *vice versa*. As the impact of exogenous production risk on household income increases with farm size, the rise in the variability of labour supply is higher for the medium farmer than for the small farmer. The large farmer is constrained in his labour-supply reaction to increased risk: he cannot work less than the minimum number of hours. Hence, the impact of a rise in risk on the variability of labour supply is largest for the medium farmer. For him, the relative increase in the variability of labour supply equals the relative increase in exogenous risk.

Changes is family labour supply appear, however, to be ineffective in absorbing additional risk. Only for unrealistically large families does the farm household's capability to smooth income *ex post* absorb a significant share of the additional risk. However, recall that adaptations in labour supply are effective in decreasing the impact of current risk. The adaptations are just not effective enough to significantly buffer an increase in risk.

The response of Aurepalle farmers to an increase in risk is slightly different. They decrease the amount of male and female labour used in crop production by about the same percentage as the increase in the inherent riskiness of land. Besides, the large farmer increases the amount of fertiliser used. These changes lead to a small decrease in mean crop production for all three farmers. As was the case with the Kanzara farmers, the changes in input use do not effectively buffer the exogenous increase in risk: the SD of crop output increases by about the same percentage as the increase in the inherent riskiness of land.

The Aurepalle farmers increase the mean and the variability of family labour supply in response to a rise in risk. Like Kanzara farmers, they increase harvest labour supply when crop income turns out to be low *and vice versa*. Besides, they increase planting labour supply in order to forestall some of the negative effects of possible yield losses. Not surprisingly, the increase is highest for the large farmer, who faces the largest absolute increase in risk. Combined with a slight to negligible increase in crop income resulting from a rise in risk, the increase in planting labour supply results in a higher average full income during the harvest stage. Hence, harvest-stage labour supply decreases somewhat, but not enough to cancel the increase in planting labour supply.

Table 6.7. *Ex ante* smoothing of a 10% increase in inherent riskiness of land in Aurepalle

	small	medium	large
% increase in planting-labour supply	5.0	7.5	8.5
resulting % increase in mean total income	0.9	0.8	0.4
resulting % increase in CV total income	-0.9	-0.8	-0.4

Table 6.7 elaborates on the *ex ante* risk management of Aurepalle farmers. The risk elasticity of planting labour supply is quite high for all three farmers. Nevertheless, the rise in labour supply resulting from a 10% increase in risk results in less than a percentage increase in mean total income. Consequently, the impact of *ex ante* smoothing on the CV of total income is small for all three farm types. This explains the conclusion of Chapters 4 and 5 that the option to use family labour for *ex ante* risk management does not affect farmers' decisions on input use.

6.3.4. Family size

Just like the impact of an increase in the inherent riskiness of land, the effects of an increase in family labour were simulated. It was reported in the previous chapters that, at least in Kanzara, the labour endowment is an important tool for risk management and thus affects the level of crop inputs. Disappointingly, Table 6.8 shows that the changes in input use resulting from a 10% increase in the family labour endowment do not affect crop income considerably.

Table 6.8. The impact of a 10% increase in family labour (% increase)

	Aurepalle			Kanzara		
	small	medium	large	small	medium	large
Input use						
male labour	0.0	0.0	0.0	-2.1	-2.1	-2.1
female labour	0.0	0.0	0.0	0.0	0.0	0.0
inorganic nitrogen	-	-	0.0	-	-3.9	-18.7
bullock traction	0.0	0.0	0.0	0.0	0.0	0.0
Crop output						
mean output	0.0	0.0	0.0	-0.2	-0.4	-1.0
SD output	0.0	0.0	0.0	0.0	-0.2	-0.8
CV output	0.0	0.0	0.0	0.2	0.2	0.2
Crop income						
mean crop income	0.0	0.0	0.0	0.1	0.0	-0.7
SD crop income	0.0	0.0	0.0	0.0	-0.2	-0.8
CV crop income	0.0	0.0	0.0	-0.1	-0.2	-0.2
Total family-labour supply						
mean labour supply	9.4	12.1	15.0	7.1	7.6	12.8
mean labour supply per capita	-0.6	1.9	4.5	-2.6	-2.2	2.6
SD labour supply	0.0	0.0	0.0	0.0	-0.1	3.9
CV labour supply	-8.6	-10.8	-13.0	-6.6	-7.2	-7.9
Income						
mean total income	6.8	4.3	1.5	5.7	2.9	1.1
mean total income per capita	-2.9	-5.2	-7.7	-3.9	-6.5	-8.1
SD total income	0.0	0.0	0.0	0.0	-0.2	-2.7
CV total income	-6.3	-4.1	-1.5	-5.4	-3.0	-3.7

A rise in family labour induces the Kanzara farmers to decrease the use of male labour and inorganic nitrogen. The purpose of this reduction of inputs is to spend less on yield stabilisation. However, fertilisers technically increase yield variability, and the effect of male labour on input variability is negligible. Yet, the input reaction of the farm households hardly affects the mean and SD of crop production and crop income.

As family size hardly affects the variability of crop income, it does not substantially affect the SD of labour supply for the Kanzara small and medium farmer. Because of the existence of a minimum boundary for harvest-labour supply, addition of family members involves a surprisingly large increase in the SD of labour supply for the large farmer: the minimum boundary is less often binding for a household with more family members.

Aurepalle farmers do not adapt input use in response to a change in the family labour endowment. Hence, additional family members do not increase any of the indicators related to crop production and income. Consequently, family size does not affect the variability of labour supply either.

Not surprisingly, an increase in family size leads to a rise in total labour supply for all six farmers. The Aurepalle small farmer and the Kanzara small and medium farmers, whose main source of income is family labour, decrease per capita labour supply. This indicates that there are economies of scale in consumption: adding an additional consumer requires adding less than proportional income to obtain the same utility of income. For example, the household does not need to add a new room to the house or to buy new pots and pans. The other farmers increase per capita hours worked. They must (at least partly) compensate a large drop in per capita crop income. This drop is higher than the economics of scale associated with the additional consumer. The overall result of increasing family size is a percentage decrease in per capita income that is smaller than the percentage increase in family members. Moreover, the CV of total income decreases as the share of labour income rises.

6.4. Covariate yields and equilibrium wages for the harvest stage

The previous analyses focus on the impact of production risk on farm-household behaviour. All other variables are assumed to be deterministic.[25] Prior research justifies this focus on production risk as opposed to price risk. Nevertheless, production risk may imply stochastic harvest-stage wage rates. Village labour markets are insular and crop production provides the bulk of employment. A village-wide negative yield shock would lead to a decrease in total labour demand and an increase in total labour supply, and thus to lower wage rates. Consequently, farmers would face low crop income and low harvest wage rates at the same time. If this were the case in the study villages, the above simulations would overestimate the stabilising impact of family labour. The bias may be especially large in the high-risk village of Aurepalle.

In this section, the impact of stochastic wages on harvest-stage labour income is analysed. First, a description is given of how a set of covariate shocks and corresponding wage rates is created. Next, the changes in simulated household behaviour resulting from stochastic harvest wage rates as opposed to deterministic wage rates are described.

6.4.1. Harvest wage rates and covariate shocks

When the harvest-stage labour market clears, the wage rate (w) is such that labour demand equals labour supply:[26]

$$\sum_{i=1}^{N} L_{2,i}(w_2, Q_i) + D_2(w_2) = \sum_{j=1}^{M} R_2(w_2) + \sum_{i=1}^{N} F_2(w_2, Q_i), \tag{6.1}$$

where L depicts farm labour demand and D demand for nonfarm labour. R represents labour supply by the landless, and F labour supply by farm households. Q is crop production. N is the number of farm household in the village, while M is the number of landless labour households. The subscript 2 indicates that the variables concern the harvest stage.

Inserting the functional forms introduced in Chapters 3 and 4 gives

$$\begin{aligned}&\sum_{i=1}^{N}\left(\chi_{0,i} w_2^{\chi_1} Q_{2,i}^{\chi_2}\right) + \eta_0 w_2^{\eta_1} = \sum_{j=1}^{M}\left(\delta_{1,j} + \delta_1 w_2 + \delta_2\left(Y_{e,j} + wT_j\right)\right) + \\ &\sum_{i=1}^{N}\left(\phi_{0,i} + \phi_1 w_2 + \phi_2\left(Q_{2,i} - K_i - w_2 L_{2,i} + w_2 T_i\right)\right)\end{aligned}, \tag{6.2a}$$

where Y_e represents landless exogenous income and planting-stage labour income, T is the total time endowment, and K summarises net planting-stage expenses. Note that similar functional forms are assumed for labour supply by landless and farm households (linear) and for labour demand by farmers and the nonfarm sector (double logarithmic).

Substituting Eqs (3.1) and (3.2) for crop output and inserting the harvest labour demand function in farmers' harvest-labour supply gives

$$\begin{aligned}&\sum_{i=1}^{N}\left(\chi_{0,i} w_2^{\chi_1}\left(f_i + h_i(\varepsilon_t + \varepsilon_i)\right)^{\chi_2}\right) + \eta_0 w_2^{\eta_1} = \sum_{j=1}^{M}\left(\delta_{1,j} + \delta_1 w_2 + \delta_2\left(Y_{e,j} + wT_j\right)\right) + \\ &\sum_{i=1}^{N}\left(\phi_{0,i} + \phi_1 w_2 + \phi_2\left(f_i + h_i(\varepsilon_t + \varepsilon_i) - K_i - w_2\left(\chi_{0,i} w_2^{\chi_1}\left(f_i + h_i(\varepsilon_t + \varepsilon_i)\right)^{\chi_2}\right) + w_2 T_i\right)\right)\end{aligned}, \tag{6.2b}$$

where ε_t is the covariate shock and ε_i the idiosyncratic shock.

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[25] The regressions include expected output prices, but they do not account for possible effects of price uncertainty.

[26] There are, of course, multiple determinants of labour supply and demand (see chapters 3 and 4). The balance presented mentions only those directly affected by a village-wide yield shock. The output price is, *e.g.*, determined at the regional level and, therefore, not affected by a village-level yield shock.

Calibration of the above labour balance yields a set of covariate shocks and associated wage rates. This requires estimates of the coefficients for the farm-household labour supply and demand functions, the landless labour supply function, and the nonfarm labour demand function. Chapters 3 and 4 present the farm-household functions. The remaining functions are discussed below.

As the ICRISAT data provide information on landless as well as cultivator households, estimation of harvest labour supply by the landless is straightforward. Nevertheless, the limited variability of labour supply in combination with a relatively small number of cases prevents satisfactory estimation of a labour supply function for Kanzara.[27] In this village, total labour supply by the landless is assumed to be independent of the harvest wage rate.

Table 6.9 presents the estimates for harvest labour supply by landless households in Aurepalle. The independent variables are similar to those in the harvest labour supply function for farmers: labour endowment, full income, asset ownership, and a time trend. Obviously, labour supply rose with the number of adults. The wage elasticity of labour supply was positive, as expected for poor households. Moreover, like farm households, the landless decreased labour supply in response to a rise in full income (see Chapter 3). The impact of liquid assets on landless labour supply was negative, as was found for Kanzara farmers (see Table 3.3). Finally, labour supply decreased over the years.

Table 6.9. Fixed effect estimates for harvest labour supply by the landless in Aurepalle (1979-1984)

N=44	Coefficient	Standard error
adults	521.592***	154.572
harvest wage rate (Rs/hr)	6283.80*	3284.39
full income (1000 Rs)	-237.176***	82.9668
liquid assets (1000 Rs)	241.789*	127.972
livestock (1000 Rs)	233.222	182.319
year	-670.407***	256.180
Adjusted R^2	0.49	

Notes: All monetary values are in 1983 prices
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01, levels, respectively

The data set provides information on nonfarm employment for the sample households. Nevertheless, six years of data are not enough to estimate aggregate nonfarm labour demand functions. Therefore wage rates are simulated for two different assumptions about nonfarm

[27] None of the coefficients was significant. Moreover, most coefficients had counterintuitive signs.

employment: i) nonfarm labour demand is fixed; ii) nonfarm labour demand has a wage elasticity of -1.

For calibration of the labour balance, idiosyncratic shocks for each farm household and a set of 1000 covariate shocks were generated. By definition, the distribution of the total shock is $N(0,1)$. A significant part of this shock is idiosyncratic. Kochar (1999) states that village-year dummies explain only 40% of the variance of kharif profits in real Rupees in Aurepalle and 33% in Kanzara. Hence, the distribution of the covariate shock is assumed to approximates $N(0,\sqrt{0.4})$ in Aurepalle and $N(0,\sqrt{0.33})$ in Kanzara. Accordingly, the distribution of the idiosyncratic shock is $N(0,\sqrt{0.6})$ in Aurepalle and $N(0,\sqrt{0.67})$ in Kanzara.

The labour balance holds for an entire village, while the data provide information for a sample only. Simulation for a limited sample may create a bias in the resulting wage rates. The sample is, therefore, duplicated as many times as necessary to reach the size of the village. By doing so, the difference in sample representation between farm households and landless households is accounted for. Each farm household in the extended data set gets a draw of the idiosyncratic shock.

At a covariate shock of 0, labour supply and demand as defined above should balance for the average harvest-wage rate used in section 6.3. Unfortunately, total labour supply and demand do not balance in the data set in any of the survey years. To correct for this, total labour supply is multiplied by a factor μ, which is set to balance supply and demand with covariate shock 0 at the average harvest-stage wage rate from section 6.3.

Table 6.10 and Figure 6.1 present the wage rates simulated for Aurepalle, where the covariate shock is highest. A similar series of wage rates could not be determined for Kanzara, where the estimated wage elasticity of labour supply is 0 for the landless and all but the largest farmers, and negative for the largest farmers (see Appendix 4). Combined with a negative wage elasticity of labour supply, this impedes equating the labour supply and demand for different shocks.

Table 6.10. Stochastic harvest wage rates for Aurepalle

	wage elasticity nonfarm employment = 0	wage elasticity nonfarm employment = -1
mean	0.48	0.48
minimum	0.45	0.46
maximum	0.52	0.50
CV	2	1

The relation between the covariate shock and the harvest-wage rate is almost linear. The effect of covariate shocks on wage rates is highest when nonfarm labour demand is inelastic. In this situation, the agricultural labour market must buffer all changes in labour supply in response to a covariate shock. The wage rate has a CV of only 2% and 1% for a nonfarm wage elasticity of 0 and -1, respectively. These CVs are much smaller than the CVs of output for individual farmers. The spread of wage rates is small: 0.45-0.52 for inelastic nonfarm labour demand and even smaller for elastic nonfarm labour demand.

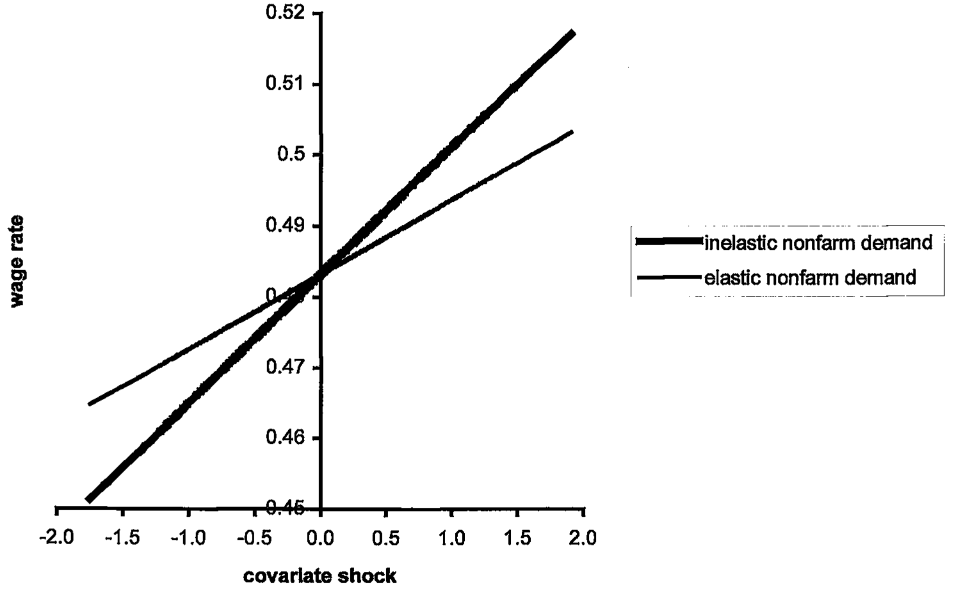

Figure 6.1. Stochastic harvest wage rates in Aurepalle

6.4.2. Stochastic harvest wages and household labour allocation and income

All simulations for the Aurepalle farmers were repeated with the generated series of covariate shocks and wage rates and a new set of 1000 idiosyncratic shocks. The mean wage rates equal the deterministic harvest wage rates used in section 6.3, and the sums of the covariate shock and the individual shock match the shocks used for simulation with deterministic wages. Consequently, differences between the two sets of analyses result from wage variability alone.

The impact of stochastic wage rates on the level and variability of income and labour supply is marginal (see Table 6.11). The relative change in the SD of labour supply for the small farmer may seem impressive, but implies nothing more than a decrease from 13 to 11 in absolute terms. The absolute changes in the standard deviation of labour supply are hardly higher for the medium and the large farmer.

Table 6.11. The impact of stochastic harvest wage rates: % changes to deterministic wages

	Aurepalle		
	small	medium	large
Mean values			
crop income	0.2	0.2	0.1
	(1)[a]	(2)	(9)
labour supply	0.0	0.0	0.0
	(0)	(0)	(-1)
total income	0.1	0.1	0.1
	(1)	(2)	(8)
Standard deviations			
crop income	0.3	0.4	0.5
	(1)	(2)	(9)
labour supply	-11.8	-6.0	-1.4
	(-3)	(-3)	(-3)
total income	4.6	1.9	0.7
	(14)	(13)	(19)

Note: [a] Absolute changes are in parentheses.

Table 6.12. The impact of exogenous changes on the SD of income and labour supply: stochastic vs deterministic wage rates

	Aurepalle		
	small	medium	large
10% increase in risk			
crop income	7.4[a]	8.4	10.0
	(7.4)[b]	(8.4)	(10.0)
labour supply	8.3	8.9	9.9
	(7.4)	(8.4)	(9.8)
total income	7.1	8.2	10.0
	(7.4)	(8.4)	(10.1)
10% increase in family labour			
crop income	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)
labour supply	0.8	0.4	0.1
	(0.0)	(0.0)	(0.0)
total income	0.3	0.1	0.0
	(0.0)	(0.0)	(0.0)

Notes: [a] % increase with stochastic wage rates.
[b] % increase with deterministic wage rates is in parentheses.

Given the limited impact of wage variability on the base-run simulation, it is not surprising that the stochastic nature of wage rates hardly affects the impact of exogenous changes in production risk and family labour. There is no effect on the percentage changes of the levels of income and labour supply, and the impact on the variability of income and labour supply is extremely small (see Table 6.12). Summarising, stochastic wage rates have little effect on household behaviour in the study villages. It appeared impossible to simulate the effects of wage variability in Kanzara, but these are most likely even smaller than the effects found for Aurepalle.

6.5. Conclusion

This chapter summarised the main findings of the previous chapters, and in doing so it raised some questions that have yet remained unanswered. Chapters 3 to 5 showed that labour income significantly affected the stability of total household income and the use of inputs in risky crop production in the two study villages in India's SAT. Farm households used family labour as well as crop inputs to manage income variability. What was, however, the precise impact of family labour on the level and variability of household income? And, to what extent did risk management through adapting crop inputs affect household income? Moreover, did covariate yield shocks not limit the effectiveness of income stabilisation through the labour market?

In order to answer the above questions, a simple two-stage simulation model was developed based on the analytical model and the regression results from Chapters 3 to 5. The model consists of a production function, an income equation, and reduced form equations for the use of all major inputs and household labour supply. The results of the simulations illustrate and enrich the conclusions of the previous chapters. The remainder of this section summarises the main new findings, which relate to the effectiveness of management through family labour, the translation of changes in input use into changes in household income, and the impact of stochastic harvest wage rates.

The simulations show that the presence of a stable flow of labour income explains most of the difference between the level and CV of crop income and total income. Moreover, this flow of income prevented households from experiencing large negative incomes in low-yield years. Nevertheless, there were two other stabilising effects of labour income: i) *ex ante* risk management through labour supply; and ii) *ex post* income smoothing through adapting labour supply to actual crop production.

These risk management strategies were certainly not ineffective. Their main result was an increase in minimum income. In other words, the risk management strategies made the farm households less vulnerable to downward production risk. *Ex post* income smoothing significantly increased minimum income for all farmers except small farmers in Aurepalle. The effect increased with farm size and was largest in Kanzara. Only in Aurepalle did farmers use family labour for *ex ante* risk management. The impact was largest for medium farmers, who increased minimum income by about 30%. These farmers had sufficient crop income to be significantly affected by production risk and a sufficient share of labour income to allow compensation of downward yield risk.

The impact of changes in production risk on household income through changes in input use was limited. As the estimated input elasticities of mean output were low, a risk or otherwise induced change in input use translated into a much smaller change in the level and variability of output. As farm households are assumed to behave rationally, the real effects may have exceeded the effects shown by the simulations.

The impact of changes in the endowment of family labour on crop income was negligible in both villages. The results from the previous chapters suggest that family labour had a positive impact on crop income in Kanzara. As farm households in this village used family labour to counteract negative production shocks, households with a large labour endowment could use input levels closer to the point of profit maximisation. However, this had only a small impact on crop income in the simulation model.

Finally, simulations reveal that harvest-wage variability had little effect on household behaviour. Harvest-wage rates were quite stable and are influenced only to a small extent by covariate yield shocks. In Aurepalle, the study village with the highest covariate risk, the CV of wage rates resulting from production risk was 2% at most. Not surprisingly, this variability had a limited impact on farm-household behaviour. This may come as a surprise to those who consider covariate weather variability the main source of production risk in the semi-arid tropics. However, weather and its impact differ between farmer's fields on a scale as small as a single village in India's SAT.

In conclusion, labour markets were important for income stabilisation of farm households in the two study villages, but simulations did not demonstrate a noteworthy impact of this behaviour on income from crop production. Labour market flexibility allowed households to adapt labour supply to the riskiness of their land and land use system and to the outcome of their production process. This behaviour specifically affected the level of income they earned in adverse years. Although labour markets were mostly agricultural, yield covariance did not inhibit risk management behaviour. The production environment was sufficiently diverse to rule out situations in which all farmers had low yields and supplied much labour. This does not, however, imply that public works are ineffective instruments for income smoothing. Nonfarm employment may not be needed to compensate for periodical shortages of harvest employment, but dry-season employment expands the period in which households can increase their workload to compensate for low crop incomes.

7. NONFARM INCOME AS A STIMULUS OF CROP PRODUCTION:
Evidence from India's Semi-Arid Tropics

While at the aggregate level of the regional economy, rising farm income may spur nonfarm activities, at the level of the household, rising nonfarm income may stimulate advances in agriculture. Off-farm income can decrease the variability of total income and increase household liquidity. This can result in an increase in agricultural productivity. However, off-farm activities may also decrease the amount of resources used in agriculture. Previous research has shown that the impact of off-farm income on crop production and income depends on the technological and market environment. This chapter shows the impact of timing, productivity, and riskiness of off-farm income on crop income. As these factors vary between various streams of income, distinct off-farm income sources affect crop income differently. Nonfarm development appears to stimulate crop production if it generates employment at a return higher than the casual agricultural wage rate, but does not become the farmers' main interest.

7.1. Introduction

Much has been written to show how rising agricultural income stimulates the growth of nonfarm activities in rural areas and small towns (*e.g.*, Delgado et al, 1994; Haggblade et al, 1989; Hazell and Haggblade, 1991; Batty and Vashistha, 1987). Growth in farm income provides an expanding market for consumption goods and agricultural inputs produced by the nonfarm sector. The impact of a small percentage growth in agriculture on nonfarm growth can be large because of the large mass of agriculture: agriculture occupies most of the land, labour, and capital of a low-income region. Moreover, consumption patterns resulting from modest agricultural incomes tend to favour demand for domestically produced, labour-intensive products (Mellor, 1995). Nevertheless, since the early 1960s the link between agricultural development and growth in the rural nonfarm sector tended to break down in India. Forces originating outside the agricultural sector, high and rising per capita incomes in the rural and urban nonfarm sector, and public and private investment in both rural and urban areas, now account for most of the increase in rural workforce participation in nonfarm activities (Bhalla, 1997).

Autonomous developments in the nonfarm sector suggest a different research perspective: How does nonfarm growth affect the agricultural sector? While at the aggregate level of the regional economy, rising farm income may (or may not) spur nonfarm activities, at the level of the household, rising nonfarm income may stimulate advances in agriculture (Evans and Ngau, 1991). Income from activities outside the family farm is an important source of cash, which potentially improves farm productivity if it is used to finance farm-input purchase or longer-term capital investments (Collier and Lal, 1986). Moreover, nonfarm income may help reduce the variance of overall household income and improve food security by allowing the household to buy food in cases of yield shortfalls (Reardon et al., 1994; Reardon, 1997). Households may then be able to increase the riskiness and profitability of crop production (Sakurai and Reardon, 1997). Thus, in a situation where agricultural productivity is relatively stagnant, a growing nonfarm sector could be a stimulus for agricultural development.

Unfortunately, the impact of nonfarm income on on-farm production is not necessarily positive. Instead of freeing funds for agriculture, nonfarm activities may compete for the same resources. Hence, well-intended policies to exploit positive interactions must be based on sound insights into the precise nature of the relationship between the various activities.

Existing empirical evidence allows some generalisations about the impact of the technological and market environment on farm-nonfarm relations. First, nonfarm activities will divert resources from the farm unless crop production is relatively profitable. In South Africa, for example, nonfarm employment has pulled labour out of stagnant agriculture as a result of which agricultural production declined. On the other hand, agricultural productivity growth in Taiwan was sufficient to prevent increasing nonfarm employment possibilities from resulting in declining agricultural production and income (Low, 1981). Second, the market environment shapes the relation between farm and nonfarm activities. Farmers use nonfarm income to purchase fertiliser in Senegal, where credit is scarce (Kelly, 1988; Reardon and Kelly, 1989). Similarly, off-farm income increases expenditures on variable farm inputs by liquidity constrained Ethiopian farmers (Woldehanna, 2000). By contrast, nonfarm activities extract resources from agriculture in Botswana, where local labour markets are missing: farmers rejected labour-intensive maize hybrids because they wanted to devote labour to nonfarm activities such as migration to the mines (Low, 1986).

Besides the farmer's production environment, the characteristics of the respective income flows affect the relation between farm and nonfarm income. These characteristics include the timing as well as the intra- and inter-household distribution and control (Reardon et al., 1994). Evidence on the impact of these factors is scarce, as it requires disaggregated income data for farmers with several sources of income: one needs to know not only the level and riskiness of each income source, but also the distribution of the various income flows over the year.

This chapter contributes to the existing understanding on farm-nonfarm relations by exploring how the nature of a stream of noncrop income determines its effect on net crop income in India's SAT. In doing so, it takes a somewhat different perspective than the previous chapters. Labour income is no longer considered as a uniform flow. On the contrary, the analysis includes labour income from off-farm sources only and distinguishes between casual farm employment, casual nonfarm employment, and regular employment. In addition, three minor sources of noncrop income are considerd: nonfarm self-employment, transfers and livestock production[28]. These six income sources differ with respect to timing, profitability, and access barriers.

The preceding chapter points out that the family labour endowment, being a tool for risk and liquidity management, had only a limited impact on net crop income. The main cause of this limited impact is the relatively small (and sometimes negative) input elasticities in the estimated production function, which may not completely capture the actual production process (see Chapter 3). Besides, aggregating all family labour as a single potential income source may obscure the effect of differences in access to off-farm activities. Most labour was traded in the casual agricultural labour market, which is accessible to all healthy adults. However, the survey households also supplied labour to the casual nonfarm labour market, the regular labour market, and nonfarm self-employment. This chapter goes beyond considering the family labour endowment as a uniform potential source of income and looks at the impact of earned income from different sources outside the family farm.

The chapter starts by setting out a conceptual framework for analysis and by outlining the possible effects of off-farm income and net crop income. Owing to the subtlety of differences between various sources of income, the framework is much more informal than the model presented in the previous chapters. Next, the chapter provides background information on the different income sources. This information is used to examine the postulated relationships between off-farm and crop income using regression analysis. The results confirm that even within a given production environment, different sources of off-farm income have a different impact on crop production. The nature of the income stream

[28] Livestock production is largely independent of land ownership, as common wastelands are an important source of fodder.

determines not only the magnitude of its effect on net crop income, but also the direction of the effect. This has important implications for rural development policies.

7.2. The potential impact of nonfarm earnings on crop production

7.2.1. Approach and issues

The basic approach outlined in Section 2.6.1, is extended in this chapter, and the farm household is considered as a complex of the farm firm, the consumer household, the worker household, and possibly the nonfarm firm. The household maximises the utility of income and home time by allocating labour time and capital resources to various farm and off-farm activities. Productive activities differ in profitability, riskiness, the requirements of fixed and working capital, and other entry barriers (*e.g.*, caste and capital requirements). The household is risk averse and limited in its choices by budget and time constraints, asset ownership, and technology.

As risk markets are missing, agricultural production cannot be considered in isolation from other productive activities and the characteristics of the consumption and labour sphere of the farm household (Singh *et al.*, 1986b). Wealthy households can take more risk and, hence, allocate their resources to riskier, but more profitable, activities (Rosenzweig and Binswanger, 1993). Capital constraints could further limit the engagement of resource-poor households in profitable activities. The results from the previous chapters, nevertheless, indicate that credit constraints are not binding in the short run.

There are several ways in which engagement in noncrop activities can increase net crop income for a farm household as described above (see Figure 7.1). Petty trade or other off-farm activities can increase a farmer's access to input and output markets. Off-farm employment may also enhance farm management skills. For these effects, engagement in the activity is what matters, not the level of activity or income. This is not the case for the other potential relations.

Crop and noncrop activities may compete for resources. Competition for family labour is a prominent phenomenon in West Africa's SAT, where farmers mostly rely on family labour for crop production (Fafchamps, 1993). The well-developed Indian rural labour markets presumably counter this effect at the household level — although not necessarily completely.[29] Activities may also compete for capital resources. Reardon and Islam (1989) point out that in a degrading and unstable environment, the priority of the farm household may be to diversify away from farming. The household may want to maximise present earnings in agriculture and invest the surplus in livestock and noncrop activities. Such behaviour affects not only the level of farm assets, but also the purchase of variable inputs like fertilisers and pesticides.

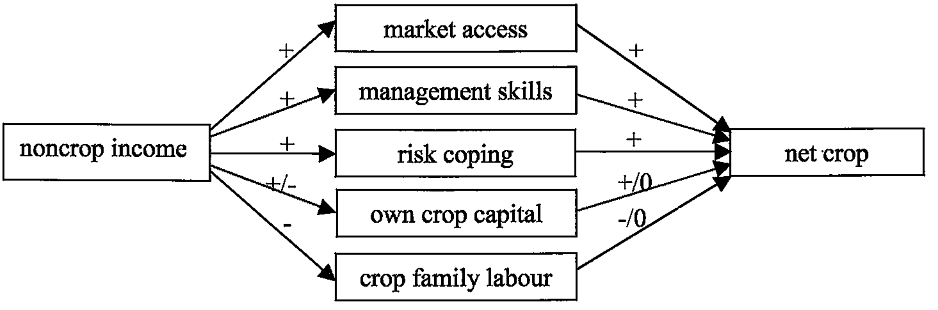

Figure 7.1. Potential effects of noncrop income on net crop income

On the other hand, noncrop income may also increase the availability of resources for crop production. In the absence of sufficient credit, noncrop income can provide the cash needed to purchase external inputs (Kelly, 1988; Reardon and Kelly, 1989). Moreover, the presence of relatively stable (or at least not completely covariate) alternative income sources will increase a farm household's risk-taking capacity. This may stimulate investment in risky crop technologies and increase crop income.

The joint effect of the processes described above depends on the nature of rural markets and the characteristics of the alternative income sources. Activities differ in their profitability and resource requirement. Further, the timing and riskiness of the income flow vary between activities. Timing of the activity relative to crop production determines its effects on liquidity, while the variability of income and the covariance with farm income controls the extent to which households can use the income source to manage risk. Finally,

[29] At the regional level, well-functioning labour markets will not prevent the substitution effect of nonfarm labour for farm labour. Nonagricultural job opportunities may pay better than farm jobs, and thus drive up the competitive farm wage, increasing capital intensity of farming and/or leading to a shift to less labour-intensive crops (Reardon, 2000). On this scale, the size of the effect depends on the stage of development of the off-farm sector and the availability of surplus labour in agriculture (Shand, 1986).

the generation of useful managerial skills and market contacts is restricted to a limited number of activities.

7.2.2. Estimation issues

Reduced-form profit functions were estimated to assess the effect of the various types of off-farm income on net crop income. The independent variables in the functions are cultivated area, the share of irrigated area, liquid assets, and the different noncrop incomes.[30] All income was aggregated over the agricultural year, which starts at soil preparation. Year dummies were included to account for differences in input and output prices. As theory does not dictate the functional form, interaction terms between the different income and liquidity sources and household illiquid assets were included in a first regression. As a joint F-test could not reject the insignificance of the interaction terms, the final regressions estimate linear approximations of the profit functions.

Fixed effect estimation accounts for unobserved time-independent factors like household preferences, access to credit, and managerial capacities.[31] All independent variables are considered endogenous: households can rent and fallow land, and liquidity and the engagement in various farm and nonfarm activities are part of a single livelihood strategy. The instruments used were the size of owned area, the share of owned land irrigated, the composition and education of the household, the size and composition of the livestock herd, lagged liquidity, and lagged values of off-farm income. Separate functions were estimated for the two villages to accommodate inter-village differences in production technology and the impact of off-farm income. Instruments may differ between the villages: both equations cover only instruments that significantly affect at least one of the endogenous variables.

Wage income and irrigation share are bounded at zero and only positive for a limited sample of the survey households. Nevertheless, standard fixed-effect estimation on the unbalanced panel is consistent and asymptotically normal if the error term is mean independent of the selection indicator given the individual effect and the independent variables[32] (Wooldridge, 2000). This may be a reasonable approximation and can be tested by

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[30] I tested for the significance of other factors of production: male and female family labour and the number of bullocks owned. Insignificance could not be rejected at the 20% level, which suggests that hiring markets work sufficiently well to consider labour and bullock traction as variable inputs.

[31] This approach prevents biases due to unobserved individual effects, but, unfortunately, also averages out the structural effects of off-farm employment on crop production through their impact on market access and management capacities.

[32] Selection in all time periods can be correlated with the independent variables or the individual effects.

inclusion of the lagged selection indicator in the regression. As Hausman tests could not reject independence in any of the equations, Standard fixed-effect regression was used to create instruments on the restricted sample.

7.3. Income diversification in India's SAT

Interpretation of the effects of various sources of income on net crop income requires insight into the characteristics of the individual income streams. The detailed ICRISAT data provide information about several income sources for many different households in India's SAT (see Table 7.1). These data allow the analysis of the determinants of each source of income (Tables 7.2-7.6) and the timing of the various income flows (Figure 7.2). Finally, the long-term character of the data allows us to gain insight into the between-year variability of the income flows (Tables 2.3-2.4).

Only for large-farm households, did crop income encompass more than half of total household income. The second important source of income was the labour market, which was the focus of Chapters 3 to 6. Other income sources were livestock, nonfarm self-employment, and inter-household transfers. Although the variability of income from the different noncrop sources was high, total household income was much more stable than crop income (see Table 2.3). The remainder of this section discusses the various sources of noncrop income in detail.

Table 7.1. Descriptives of the two study villages (1979-1984)

	Aurepalle (N=161)		Kanzara (N=162)	
	mean	standard dev.	mean	standard dev.
net crop income (Rs)	3183.59	4411.10	4833.60	7222.30
livestock income (Rs)	1835.71	4031.79	1479.20	2470.33
self-employment income (Rs)	1319.93	1835.30	354.018	1181.27
casual farm wages (Rs)	553.264	612.584	857.581	814.554
casual nonfarm wages (Rs)	573.570	3239.22	326.282	824.986
regular wages (Rs)	255.115	595.424	1279.42	2346.01
transfers (Rs)	-282.264	750.870	-123.450	622.634
liquid assets (Rs)	7281.91	9067.50	5356.15	11289.1
cultivated area (ha)	3.88012	3.40179	4.97549	6.57568
irrigated area/cultivated area	0.12462	0.19997	0.05751	0.14838

Note: All monetary values are in 1983 prices.

Transfers

Transfers were a minor source of income for the study households: on average, net income transfers were negative. As expected, wealthier households transferred larger sums of money to relatives than poorer households did. Previous year income from nonfarm self-employment (which was positively related to current income from the same source) increased the outflow of transfers. Surprisingly, an increase in land ownership decreased the outflow of funds (or, alternatively, increased the inflow of funds) in Aurepalle. This may be the reaction to a purchase of land, which erodes the household's reserves. In Kanzara, current outflows led to lower outflows or even inflows in the following year. This points at the reciprocity and/or incidental nature of transfers. Part of the transfers went to in-laws: additional women increased outflows. Most transfers took place during the dry season, when uncertainty about crop income was resolved. Nevertheless, these transfers had little effect on income stability: on average, gifts and remittances reduced the variability in cultivators' net crop income by less than 1 percent (Rosenzweig (1986), according to (Walker and Ryan, 1990))

Livestock production

Simple bivariate correlations show that households with large endowments of land and liquid assets earned most income from livestock production. This is not surprising: livestock activities require a considerable investment, which may prevent poorer households from entering this activity. In Kanzara, land ownership directly increased livestock income. Large landowners had easier access to fodder, and hence a higher livestock income. This effect was not found in Aurepalle.

Dairy was the major source of livestock income. In Aurepalle, bullocks also contributed significantly to income, while young cattle represented a significant cost. Liquid assets decreased livestock income, presumably because farmers used these assets to purchase new livestock. The same holds for previous year income from self-employment in Aurepalle. Women appeared to be the main caretakers of productive animals: the more women, the higher the livestock income. In Kanzara, secondary education increased livestock income. Highly educated households may get better prices for their products.

The between-year variability of livestock was very high, especially for small farmers. The composition of the herd explains at least part of the difference in variability between the three farm-size groups. Small farmers mostly owned small stock and derived a relatively large share of their income from sales. Large farmers also owned dairy animals and bullocks, which provided a relatively stable stream of income from milk and draught power. Contrary to expectations, the variability of livestock income was comparable in drought-prone Aurepalle and rainfall-assured Kanzara. The limited covariance of yields apparently prevented periodical fodder shortages.

Table 7.2. Probit estimates for off-farm income (1979-1984)[a]

	Aurepalle (N=161)			Kanzara (N=162)		
	nonfarm wages	permanent wages	self-employment	nonfarm wages	permanent wages	self-employment
Agricultural resources						
land owned (ha)	-0.16696*	-0.02567	0.08547*	-0.06471	-0.11222	0.21628***
	(0.10027)[b]	(0.04541)	(0.04661)	(0.06392)	(0.15183)	(0.05987)
irrigated/total owned	-0.20662	-8.74361***	0.38894	0.21405	-4.32534	0.07944
	(1.04330)	(2.43729)	(1.25009)	(0.67206)	(3.11259)	(0.85380)
bullocks	0.56242***	0.06811	-0.18877	-0.46619***	-0.01140	-0.67651***
	(0.21550)	(0.17100)	(0.15984)	(0.14450)	(0.31769)	(0.15837)
dairy animals	0.64120***	0.18848	0.08573	0.00376	0.22281	0.40981***
	(0.17850)	(0.15890)	(0.15080)	(0.15664)	(0.30628)	(0.12063)
young cattle (Rs)	-0.00307***	-0.00083	-0.00012	-0.00059	-0.00412**	-0.00109**
	(0.00059)	(0.00052)	(0.00029)	(0.00064)	(0.00203)	(0.00043)
Previous year liquidity & income						
liquid assets (Rs)	-0.00023***	-0.00001	0.00011***	0.00011***	-0.00014*	-0.00004
	(0.00006)	(0.00004)	(0.00003)	(0.00003)	(0.00008)	(0.00003)
transfers (Rs)	-0.00081***	0.00060	0.00160***	0.00039	-0.00053	0.00013
	(0.00029)	(0.00047)	(0.00039)	(0.00030)	(0.00043)	(0.00029)
self-employment dummy (yes=1)	-1.43139***	-0.11940	1.64537***	0.58287**	-0.00847	1.26317***
	(0.48994)	(0.39801)	(0.33679)	(0.25265)	(0.47083)	(0.33534)
farm wages dummy (yes=1)	0.22634	1.00649*	0.96963	0.75484	-8.70804**	0.61698
	(0.59699)	(0.54217)	(0.68908)	(0.51884)	(3.97290)	(0.44834)
nonfarm wages dummy (yes=1)	0.63791	-0.03881	0.66495	0.89927***	-0.56913	0.38471
	(0.47423)	(0.43440)	(0.45112)	(0.31610)	(0.44188)	(0.32833)
permanent wages dummy (yes=1)	-0.52223	2.98066***	0.52410	0.83879***	11.7306***	0.10361
	(0.44186)	(0.58584)	(0.37057)	(0.28441)	(4.10236)	(0.31477)
Family characteristics						
adult men	-0.18570	1.11354***	-0.03643	-0.12588	-1.45745***	0.25780*
	(0.19766)	(0.35394)	(0.21339)	(0.14672)	(0.42892)	(0.15215)
adult women	0.72734*	-0.95106***	-0.14715	0.17255	0.83246	-0.40322
	(0.37533)	(0.22674)	(0.23368)	(0.17978)	(0.80336)	(0.25966)
women 25-44yr	-0.70030*	0.54977	0.63245*	-0.59422***	-0.26325	-0.00540
	(0.38767)	(0.33918)	(0.35738)	(0.17969)	(0.47680)	(0.26543)
men 45-54yr	1.15016**	-0.57066	-0.30426	0.62764**	-0.06015	-0.30410
	(0.50628)	(0.50538)	(0.39385)	(0.27671)	(0.73167)	(0.33908)
literate adults	-0.09266	-0.39282	-0.36342**	0.52753***	1.15844***	-0.02359
	(0.32719)	(0.42588)	(0.15854)	(0.13168)	(0.37407)	(0.11473)
adults with secondary education	0.52811	1.08544**	0.71681**	-0.04594	1.17072***	-0.04211
	(0.51099)	(0.43466)	(0.28612)	(0.13243)	(0.43900)	(0.14865)
intermediate caste (yes=1)	1.65741	-2.04377*	2.18208***	0.58195*	-3.52681***	1.50196***
	(1.05227)	(1.11768)	(0.73878)	(0.35321)	(0.98458)	(0.39964)
low caste (yes=1)	1.97063	-1.36098	-0.59320	1.17920***	-3.00332**	0.90463*
	(1.21026)	(1.17572)	(0.86923)	(0.43797)	(1.36272)	(0.54295)
year	0.01470	-0.03288	0.00139	-0.20074	0.16664	-0.11645
	(0.12964)	(0.12800)	(0.11827)	(0.12882)	(0.22261)	(0.08036)
constant	-3.65020	1.80565	-2.04504	13.9605	-13.0473	6.58656
	(10.3569)	(10.1086)	(9.48655)	(10.2581)	(18.0644)	(6.41592)
pseudo R^2	0.47	0.63	0.54	0.49	0.82	0.41

Notes: [a] Participation in the other income generating activities was too high to estimate the probability of participation.

[b] Standard errors in parentheses. Standard errors adjusted for dependence between observations for a single household.

All monetary values are in 1983 prices.

*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table 7.3. Bivariate correlation of income and household characteristics, Aurepalle

	crop income	livestock Income	self-employment	farm wages	nonfarm wages	regular wages	transfers
total income (Rs)	0.869***	0.863***	0.079	-0.339***	-0.039	-0.089	-0.442
land owned (ha)	0.633***	0.488***	-0.148*	-0.380***	-0.090	-0.176**	-0.363***
irrigated/total owned	0.707***	0.474***	0.036	-0.438***	-0.166***	-0.233***	-0.185**
bullocks	0.597***	0.657***	-0.011	-0.295***	-0.075	-0.153**	-0.428***
dairy animals	0.630***	0.656***	-0.118	-0.283***	0.023	-0.097	-0.297***
young livestock (Rs)	0.485***	0.384***	-0.105	-0.169**	-0.077	-0.097	-0.359***
liquid assets (Rs)	0.693***	0.782***	-0.030	-0.323***	-0.141*	-0.138*	-0.647***
men	0.323***	0.258***	0.139*	0.000	-0.056	0.300*	-0.137
women	0.161**	0.181**	0.091	0.182**	0.205***	0.074	-0.133*
literate adults	0.745***	0.584***	-0.093	-0.438***	-0.153**	-0.153**	-0.385***
sec. education	0.481***	0.463***	0.124	-0.359***	-0.105	-0.135*	-0.346***
caste	0.795***	0.603***	-0.040	-0.643***	-0.260***	-0.247***	-0.344***

Note: All monetary values are in 1983 prices.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table 7.4. Fixed effect regression of noncrop income, Aurepalle (1979-1984)[a]

	livestock (N=161)	farm wages (N=104)	nonfarm wages (N=38)	self-employment (N=161)	transfers (N=161)	regular wages (N=39)
Agricultural resources						
land owned (ha)	-209.845	-21.9703	-1809.34***	55.4298	94.2761*	-677.929
	(250.295)	(95.6792)	(437.553)	(83.4976)	(56.3050)	(594.338)
irrigated/total	5662.34	1662.66	495022	1854.70	-2576.84***	-11207.8
	(3939.74)	(1733.78)	(321624)	(1314.28)	(881.784)	(8062.48)
bullocks	717.795**	155.266*	1103.34	-205.853*	68.1018	873.891*
	(323.207)	(91.1440)	(715.895)	(107.821)	(72.2463)	(444.618)
dairy animals	901.114***	55.4230	2212.90**	-75.7505	-17.4799	385.727
	(281.624)	(76.6627)	(703.566)	(93.9486)	(60.9947)	(283.395)
young cattle (Rs)	-1.24098*	0.14050	2.76253	-0.10236	0.079058	-2.71733*
	(0.67278)	(0.16500)	(2.81847)	(0.22444)	(0.15101)	(1.35075)
Previous-year liquidity and income						
liquid assets (Rs)	-0.14734**	0.00229	-0.50275	0.03181	-0.04168***	0.13520
	(0.06800)	(0.05272)	(0.37798)	(0.02268)	(0.01529)	(0.24084)
self employment (Rs)	-0.63884**	0.05321	-2.55030**	0.53211***	-0.112001*	-0.44989
	(0.29655)	(0.08136)	(1.11045)	(0.09893)	(0.06738)	(0.28624)
Family composition						
adult men	-352.725	-182.177	1184.02*	-20.9422	71.5347	1052.20**
	(659.241)	(129.293)	(641.055)	(219.920)	(146.462)	(458.086)
adult women	-298.522	313.453**	1049.79*	368.538*	181.024	-1010.32***
	(585.045)	(119.706)	(555.183)	(195.169)	(127.238)	(339.997)
women 25-44 yr	1935.07**	168.048	1119.79	-524.331*	-111.533	2907.11**
	(796.768)	(179.121)	(1174.15)	(265.799)	(172.282)	(1104.63)
literate adults	527.298	83.9281		-344.601	1.87221	
	(646.294)	(290.705)		(215.601)	(145.082)	
Adjusted R^2	0.64	0.48	0.98	0.81	0.44	0.45

Notes: [a] Estimation includes (fixed) household and year effects. The regressions are the first stage in the 2SLS estimation of net crop income.
All monetary values are in 1983 prices
Standard errors are in parentheses.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table 7.5. Bivariate correlation of income and household characteristics, Kanzara

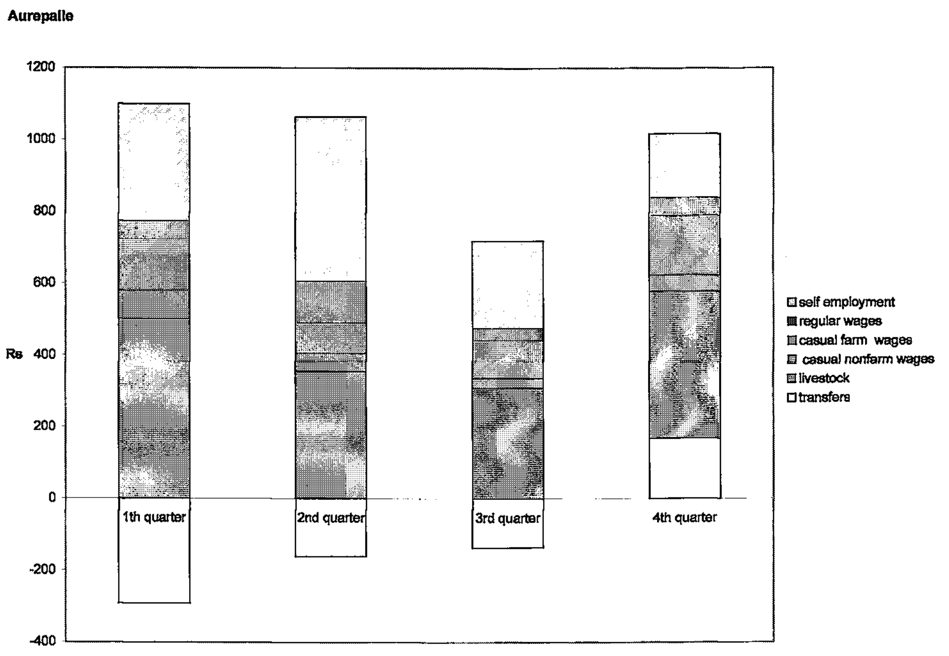
	crop income	livestock income	self-employment	farm wages	nonfarm wages	regular wages	transfers
total income (Rs)	0.944***	0.898***	-0.068	-0.385***	-0.050	0.438***	-0.389***
land owned (ha)	0.810***	0.753***	-0.146*	-0.409***	-0.147*	0.365***	-0.515***
irrigated/total owned	0.432***	0.391***	-0.119	-0.333***	-0.094	0.091	-0.055
bullocks	0.855***	0.779***	-0.151*	-0.360***	-0.172**	0.252***	-0.467***
dairy animals	0.670***	0.757***	-0.212***	-0.396***	-0.112	0.163**	-0.169**
young livestock (Rs)	0.392***	0.390***	-0.154**	-0.321***	-0.058	0.029	0.000
liquid assets (Rs)	0.799***	0.702***	-0.114	-0.412***	-0.067	0.343***	-0.372***
men	0.422***	0.385***	0.069	0.047	0.050	0.347****	-0.228***
women	0.304***	0.326***	0.227***	-0.064	-0.064	0.313***	-0.319***
literate adults	0.626***	0.605***	-0.024	-0.351***	-0.201***	0.277***	-0.334***
sec. education	0.610***	0.615***	-0.130*	-0.409***	-0.112	0.462***	-0.329***
caste	0.358***	0.365***	-0.067***	-0.408***	-0.053***	-0.063***	-0.081***

Note: All monetary values are in 1983 prices.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table 7.6. Fixed effect regression of noncrop income, Kanzara (1979-1984)[a]

	livestock (N=162)	farm wages (N=127)	nonfarm wages (N=65)	self-employment (N=162)	transfers (N=162)	regular wages (N=82)
Agricultural resources						
land owned (ha)	379.722***	183.663	-273.318	-23.4676	-164.591**	307.681
	(144.311)	(117.566)	(275.212)	(108.489)	(70.8456)	(204.198)
irrigated/total	337.366	-1192.69	-2456.70	-21.0788	319.177	-154.530
	(704.707)	(1285.40)	(2258.38)	(529.777)	(345.956)	(760.426)
bullocks	29.1705	169.649	-885.524	186.566*	59.5429	-171.081
	(139.335)	(104.467)	(431.748)	(104.747)	(68.4025)	(225.580)
dairy animals	440.322***	299.733*	-203.559	-34.3543	108.233	524.488*
	(166.455)	(153.661)	(425.887)	(125.136)	(81.7163)	(268.838)
Previous-year liquidity and income						
liquid assets (Rs)	-0.06342***	0.00584	0.03964	-0.00162	0.02026*	-0.09609**
	(0.02141)	(0.07561)	(0.03775)	(0.01610)	(0.01051)	(0.04051)
nonfarm wages (Rs)	-0.07107	0.02748	-0.48256***	-0.18392*	0.03213	-0.63183**
	(0.12671)	(0.06913)	(0.13247)	(0.09526)	(0.06221)	(0.29918)
regular wages (Rs)	0.01359	0.07400	-0.03130	-0.08341	-0.10447**	0.21360**
	(0.09606)	(0.05915)	(0.11262)	(0.07222)	(0.04716)	(0.10385)
transfers (Rs)	0.13782	-0.00828	-0.77954	0.15308	-0.25535***	-0.08854
	(0.16567)	(0.14494)	(0.57787)	(0.12454)	(0.08133)	(0.22886)
Family composition						
adult men	-71.0429	-146.241	402.901	549.917**	-146.582	-679.396
	(389.163)	(242.135)	(438.830)	(292.561)	(191.049)	(644.236)
adult women	579.211**	-94.2526	-664.620	56.6065	-228.512*	426.621
	(250.077)	(172.601)	(743.619)	(188.000)	(122.768)	(365.349)
women 25-44 yr	162.744	18.9357	-1003.13	135.969	-21.8256	-398.228
	(307.973)	(208.799)	(615.596)	(231.524)	(151.191)	(361.893)
men 45-54 yr	405.423	102.617		-893.230***	-223.866	254.629
	(476.206)	(285.368)		(357.997)	(233.780)	(768.957)
literate adults	-200.977	666.697***	-848.853	156.005	-41.6369	387.161
	(366.474)	(230.854)	(742.353)	(275.504)	(179.910)	(527.959)
adults with sec. education	3071.69***	-1678.81**		-434.304	-232.168	1843.12
	(686.541)	(823.419)		(516.120)	(337.038)	(1167.18)
Adjusted R^2	0.83	0.50	0.47	0.58	0.36	0.88

Notes: See Table 7.4.



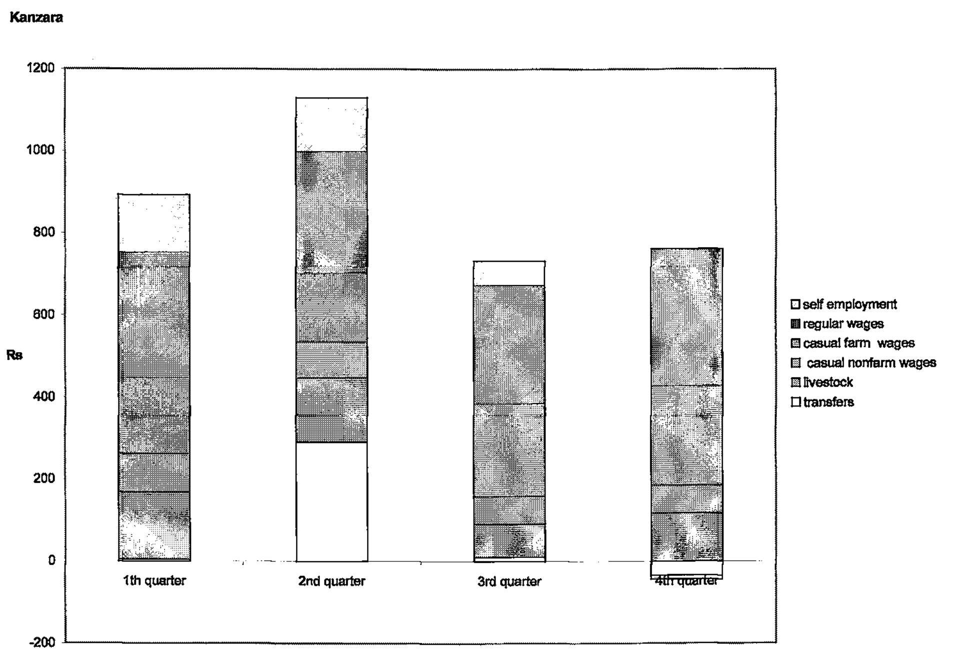


Figure 7.2. Seasonal distribution of net income for the study villages (1979-1984)

The seasonal distribution of livestock income differed between the two survey villages. In Aurepalle, income seasonality resulted from variability in the returns on livestock products. This source of income was highest in the first and fourth quarter. High sales during the first and second quarter caused the seasonal pattern of livestock income in Kanzara. In both villages, low fodder costs increased the net returns on livestock in the fourth quarter.

Nonfarm self-employment

Self-employment was especially important for small and medium-size farm households in Aurepalle, where the major nonfarm activity was the production and trade of palm wine or toddy. About one quarter of the village was involved in toddy tapping, a traditional caste occupation. The activity was closed for members of other castes. Likewise, traditional handicrafts, *e.g.*, carpentry, pottery, and basket weaving, were carried out by members of specific 'service' castes (Walker and Ryan, 1990). These service castes took an intermediate position on the social ladder.

In both villages, members from intermediate castes had the highest probability of engaging in nonfarm self-employment. Literacy decreased the probability of participation in nonfarm self-employment in Aurepalle. This reflects the relatively large importance of traditional caste activities. On the other hand, secondary education increased participation in nontraditional self-employment activities. Given participation, education did not affect the level of income obtained.

The capital requirements of nonfarm self-employment were moderate. Self-employment generally requires some fixed and working capital: *e.g.*, tools and wood for carpenters, or transportation and starting capital for petty traders. Consequently, there was a small positive impact of previous-year liquid assets and transfers on the probability of self-employment in Aurepalle. In Kanzara, income from livestock production stimulated participation in self-employment. Nevertheless, liquid assets, dairy animals, and transfers did not affect the level of income from self-employment in either village. Moreover, previous-year nonfarm wages even decreased income from self-employment in Kanzara. The impact of bullocks was diverse.

Most self-employment activities were labour intensive. There was a small positive correlation between income from self-employment and the family labour endowment in both villages. Besides, the presence of women increased participation in nonfarm self-employment and the level of self-employment income obtained in Aurepalle, where women were responsible for such activities as the sale of toddy. In Kanzara, men appeared most important for self-employment: an additional adult man increased the probability that a farm household would participate in nonfarm self-employment and the level of income generated from that source.

Large landowners did not diversify away from agricultural production. The correlation between agricultural assets and self-employment was negative in both villages. Nevertheless, an increase in landownership increased the probability that a farm household participated in nonfarm self-employment.

The between-year variability of income from self-employment was high. This variability may reflect the riskiness of the activities as well as differences in household involvement related to the variability of, *e.g.*, crop production. Nevertheless, there was some continuity in self-employment; households engaging in self-employment one year had a high possibility of doing so the following year. Moreover, a higher income from self-employment one year implied a higher income from self-employment the following year.

Self-employment income was highest in the first and second quarter. This is the period after harvest, when money is relatively abundant and people have their tools repaired and their household goods replaced. Consequently, the demand for local handicrafts is high. In Aurepalle, self-employment income was also substantial during the second half of the calendar year. This was mainly due to the seasonality of toddy production.

Casual farm wages

The main participants in the casual labour markets were illiterate households with limited agricultural and liquid assets.[33] Labour was their most abundant resource, and the casual labour market allowed them to cash this resource without the need for complementary assets. The casual farm labour market was open to all healthy adults: employers were usually indifferent about the caste or socio-economic status of prospective employees.

Women dominated the agricultural labour market, while men did most of the work on the family farm. The demand for female labour was especially high in transplanting paddy. In Aurepalle, the number of adult women in the household was, hence, the major determinant of farm wage income. Livestock induced an increase in farm wages in both villages. This indicates that the generally asset-poor households engaging in the casual farm labour markets

[33] The sample includes only farm households. Inclusion of landless households would reinforce this observation, as the landless participate actively in the casual labour market, own few assets, and have enjoyed little education.

required money to purchase fodder. Surprisingly, given that a household earned casual farm wages, literacy increased the level of wages earned in Kanzara.

As expected, the temporal distribution of farm wages followed the cropping season. In Aurepalle, castor picking generated much employment between September and January. Other labour intensive activities were transplanting and weeding of paddy in July and the paddy harvest in October. The mix of short- and long-duration crops in the assured-rainfall environment of Kanzara allowed a relatively even spread of farm-wage income over the year. There were, however, peaks in July and August, when farmers weed, hoe, and apply pesticides, and from September through December, when the various crops are harvested.

Casual nonfarm wages

Few people participated in the casual nonfarm labour market. Like those in the casual farm labour market, most of these people belonged to low-caste families with small amounts of agricultural assets. The character of the nonfarm casual labour market differed between the two villages. In Kanzara, this type of employment mostly involved participation in the public-works programme. In Aurepalle, private firms provided by far most of the casual nonfarm employment. Land and previous-year liquid assets and transfers decreased participation in the nonfarm labour market in Aurepalle. On the other hand, liquid assets increased participation in nonfarm wage employment in Kanzara. As expected, an increase in the labour endowment resulted in an increase in nonfarm wage income.

The casual nonfarm labour market seems to absorb spill-over labour supply from the casual farm labour market. Although casual nonfarm wages were earned throughout the year, they peaked in the first and the second quarter of the calendar year, when agricultural labour demand was small. The between-year variability of nonfarm wages was very high. In Kanzara, high levels of nonfarm wage income even led to low levels of nonfarm wage income in the following year.

The relation between nonfarm wage employment and other sources of income was diverse. In Aurepalle, nonfarm self-employment decreased participation in nonfarm wage employment, while livestock income increased participation in the casual nonfarm labour market. In Kanzara, previous self-employment and regular wages increased the probability of participation in the nonfarm casual labour market.

Regular wages

Although Walker and Ryan (1990) state that 'the bulk of labour income is earned in the daily rated labour market', Figure 7.2 and Table 2.4 show that regular wage income was far from unimportant, especially in Kanzara. Regular employment involved two distinct types of workers: permanent farm servants and salaried employees. The relative importance of these groups differed between the two villages.

Regular farm servants earned the bulk of regular wages in Aurepalle. These servants were men from poor illiterate low-caste families, who generally participated in the casual as well as the regular agricultural labour market. Hourly wages for regular farm servants were lower than the hourly wage for casual labourers. The dominant caste among the farm servants was a Harijan community. Employers seemingly exploited the low status of this group and their demand for loans for marriage of their children (Walker and Ryan, 1990). Moreover, farm households seemed to use regular employment to finance bullocks. Young cattle, on the other hand, lowered the level of regular wages, presumably because they require much care. Women decreased participation in the regular labour market as they were very active in the casual farm labour market and in self-employment.

In Kanzara, salaried jobs provided a significant part of regular wage income. Wealthy, highly educated farmers from high-caste families brought in the lion's share of these salaries. As in Aurepalle, regular farm wages went mostly to the poorer households. However, their status was different: the regular wage rate exceeded the rate for daily labourers. Still, irrigation, liquid assets, and casual wages decreased regular employment. The number of both men and women increased the probability of participation in regular labour markets. Due to the importance of salaried jobs and the relatively high wage rates for farm servants, the average level of regular wages was high in Kanzara compared to Aurepalle.

The term regular wages falsely suggests stability within and between years. Especially in Aurepalle, the distribution of regular wages was quite erratic. Regular farm servant contracts were exclusively on a yearly basis. Contracts were for twelve months, and wages were partly paid as lump-sum advances in the second quarter (Walker and Ryan, 1990). Nevertheless, current participation in the regular labour market increased the probability of next-year participation. The significant share of salaried jobs in Kanzara resulted in a relative stability of regular wages within as well as between years: current permanent wages positively affected next-year nonfarm wages.

7.4. Evidence of the impact of off-farm income on net crop income

Net crop income was estimated as a function of the above mentioned income sources and cultivated area. The estimation results are presented in Table 7.7, while Table 7.8 presents the elasticities at the village mean. The explanatory power of the profit functions is high: 89% in risk-prone Aurepalle and 94% in rainfall-assured Kanzara. Covariant revenue shocks explain only a limited part of the variability of crop income: without inclusion of year dummies, which account for prices as well as weather, the adjusted R^2s are still as high as 0.82 and 0.91.[34]

Table 7.7. 2SLS estimation of net crop income (1979-1984)[a]

	Aurepalle (N=161)	Kanzara (N=162)
livestock income	0.03148	0.94430***
	(0.12278)	(0.30268)
self-employment income	0.03308	0.68363*
	(0.20920)	(0.35635)
casual farm wages	-1.63521***	-0.72179*
	(0.39491)	(0.44382)
casual nonfarm wages	0.02956	0.06082
	(0.03047)	(0.08319)
regular wages	-0.53116**	0.49051***
	(0.22987)	(0.15562)
transfers	1.65584**	1.04154*
	(0.79157)	(0.57712)
liquid assets	0.17770**	0.13952***
	(0.07221)	(0.04137)
cultivated area	236.370*	301.676**
	(137.129)	(148.384)
irrigated area/cultivated area	10615.0***	-1452.82**
	(1950.24)	(723.245)
Adjusted R^2	0.88	0.94

Notes: [a] Estimation includes (fixed) household and year effects. All reported variables are instrumented. Refer to Tables 7.3 and 7.5 and Appendix 3 for the results of the first stage.
Standard errors are in parentheses.
All monetary values are in 1983 prices.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Cultivated area has the expected significant positive coefficient in both equations. The high and positive *irrigation* coefficient for Aurepalle reflects the considerable productivity differences between dryland and irrigated agriculture in this village. The same farmers who harvested dryland crops with yields ranging from 200 to 400 kg per ha received paddy yields from 4 to 5 tonnes per ha (Walker and Ryan, 1990). Irrigation was of limited importance in Kanzara. Firstly, rainfall was abundant and assured relative to Aurepalle, which enabled farmers to grow profitable dryland crops like cotton and hybrid sorghum. Secondly, the number of farmers cultivating irrigated crops was very small. The latter may cause the irrigation coefficient to pick up something other than differences in the share of irrigated area.

The significant positive coefficients for *liquid assets* confirm the importance of imperfections in insurance and credit markets. Liquid assets will increase net crop income if farmers cannot or do not want to take production loans. The previous chapters indicate that short-term credit constraints were not binding, but that households were hesitant to take a loan. They disliked the idea of having to repay a loan after a bad harvest. Hence, the household endowment of liquid assets had a positive impact on the use of crop inputs. Due to the characteristics of the estimated production function, this, however, hardly translated into changes in the simulated level and variability of crop income. Nevertheless, Table 7.8 suggests that the actual effect of household liquidity on net crop income was substantial.

Table 7.8. Income elasticities of farm labour use at mean values (1979-1984)

	Aurepalle	Kanzara
livestock income	0.02	0.29***
self-employment income	0.01	0.05*
casual farm wages	-0.28***	-0.13*
casual nonfarm wages	0.01	0.00
regular wages	-0.04**	0.13***
transfers[a]	-0.15**	-0.03*
liquid assets	0.41**	0.16***

Notes: [a] The mean value of transfers in negative in both villages. Hence, the elasticities must be read as the decrease in crop profits resulting from an increase in income transfers from the household to a third party.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

The effect of liquid assets was especially large in drought-prone Aurepalle: a 10% increase in liquid assets led to a 4.1% increase of net crop income in Aurepalle compared to a 1.6% increase in Kanzara. Aurepalle households were especially reluctant to borrow as they faced higher *ex ante* production risks and had less capacity to smooth income *ex post*.

[34] We can conclude from these numbers that the covariate shock constitutes $^3/_9 \approx 33\%$ of the total shock in Kanzara, and $^7/_{18} \approx 40\%$ Aurepalle. This coincides with Kochar's findings, which are used in chapter 6 to simulate the covariate shock.

Transfers increased net crop income as did liquid assets; only the size of the effect was smaller. The level of net transfers was uncertain at the beginning of the cropping season. Hence, transfers had only limited impact on household risk perceptions and liquidity during the cropping season. Besides, most money transfers took place only after harvest. Transfers may, therefore, have had more effect on the following-year liquidity and production than on current crop income.

It was argued in Section 7.2 that the effects of alternative sources of (earned) income are ambiguous. The impact of noncrop income depends not only on the presence of risk and credit constraints, but also on the characteristics of the income flow. The results clearly demonstrate the relevance of these characteristics: some noncrop income coefficients are positive and others are negative.

Livestock income stimulated net crop income in Kanzara. The impact of livestock income was extremely high: the livestock elasticity was almost double the liquidity elasticity. Only the presence of complementarities other than increased liquidity and risk coping can explain this impressive effect. Livestock produces manure, which can help to improve soil quality and crop production. Moreover, livestock production involves demand for fodder, a by-product of crop production. This may increase the returns on crop production by increasing the imputed price of crop by-products. In Aurepalle, livestock income did not significantly affect crop production. The more pronounced production risk in this village may explain the difference with Kanzara.

Like livestock income, *income from nonfarm self-employment* had a positive effect on net crop income in Kanzara. In this village, manufacturing provided a large share of self-employment income. Nonfarm self-employment did not compete much for labour with crop production as most activities could be executed during the dry season. Nevertheless, the self-employment elasticity of net crop income was low relative to that of liquid assets. Income from self-employment was uncertain and was mostly earned after harvest. The survey households, therefore, anticipated this type of income only to a certain extent. The effect of self-employment on next-year liquidity and crop production may have been more important than the contemporaneous impact.

Income from self-employment did not significantly affect net crop income in Aurepalle. For a number of households in this village, self-employment (*i.e.*, toddy tapping) was the main source of income. These households considered agriculture as a secondary activity and were therefore less likely to put great effort in crop production. This may be the cause of the insignificance of the self-employment coefficient. Another explanation is the existence of some positive covariance of toddy production and crop production.

Casual farm wages appear to be substitutes for crop income in both villages: *ceteris paribus* an increase in farm wages was associated with a decrease in crop income. In the semi-arid tropics, the timing of agricultural labour on and off the family's own farm necessarily coincides. Cash requirements may force farmers to work off-farm, even if they could allocate their labour more productively to own-farm production. Hired labour can substitute for family labour, but this does not solve the cash needs that lead to labour market participation.[35] Besides, for farmers earning much farm wage income, crop production is only of secondary importance for their livelihood. In both villages, the farm wage elasticity of crop income was larger than minus one. This implies that casual farm wages decreased crop income but increase total income. The absolute value of the elasticity was lower in Kanzara than in Aurepalle. Compared to Aurepalle, farm labour demand in Kanzara was spread relatively evenly over the year. This made the conflict between cash demand and crop production less serious.

The estimates do not demonstrate a significant impact of *casual nonfarm wages* on net crop income. The competition for family labour between nonfarm employment and crop production was limited, as both activities took place at largely different time periods. Nevertheless, casual nonfarm wages did not help increase net crop income, as wage rates in the casual nonfarm labour markets were low.

The impact of *regular wages* on crop income was positive in Kanzara, where regular employment was relatively remunerative. The households involved could offset the decrease in the availability of family labour by hiring labour in the market or by substituting capital for labour. The stimulus of regular wages on crop income was only slightly smaller than that of liquid assets. This reflects the high certainty of the income source.

In Aurepalle, on the other hand, regular employment decreased net crop income. Farm servants brought in the bulk of regular income. Their hourly wage rate was lower than that of casual agricultural labourers. This prevented (complete) substitution of hired labour for the family labour pulled out by regular employment. Nevertheless, the decrease in crop income was much smaller than for casual farm employment. Most farm servants belonged to the poorest households in the village, while casual farm workers belonged to small and medium-

[35] I did not observe a direct effect of the family labour endowment on crop production, because the family adults are both sources and sinks of liquidity.

farm households alike. The poorest households were relatively well endowed with labour and had more than enough family labour to meet labour demands during the peak season.

7.5. Conclusion

In an area where agriculture is relatively stagnant, like India's SAT, growth in the nonfarm sector may stimulate agricultural growth. There are two mechanisms through which this process may occur. First, farmers may use nonfarm income to invest in agricultural assets. Various studies have dealt with this topic. Savadogo *et al* (1994), for example, found that nonfarm income had a positive impact on the purchase of bullocks. Second, nonfarm income may increase current crop income. This is the focus of the present study. Nonfarm activities can increase the household's farming skills or their access to markets. Moreover, nonfarm income may boost crop income due to improvements in household liquidity and risk-taking capacity. Conversely, engagement in nonfarm activities may reduce crop income if crop and noncrop activities compete for labour and capital resources.

Previous research has shown that the sign and size of the impact of noncrop income on crop production depends on the socio-economic and biophysical environment in which a farmer operates. Even within a given environment, different sources of off-farm income will, however, have different effects on crop income. Each income source differs with respect to capital requirements, timing, and riskiness. The timing of an activity relative to crop production determines its effects on liquidity and the potential competition for family labour. The variability of an income source and the covariance with farm income controls the extent to which households can use the income to manage risk. Although the literature recognises the importance of the nature of the off-farm income stream for its effect on farm production, these aspects have received little empirical scrutiny.

Data from the study villages confirm the hypothesis that dissimilar sources of income affect net crop income differently. Activities with returns not higher that the casual farm wage rate did not stimulate crop production. If these activities require labour simultaneous to crop production, they even reduce net crop income. On the other hand, households simply substituted hired labour or capital for any family labour withdrawn from crop production if the returns on off-farm employment were high relative to the casual farm wage. What is more, the households used part of the off-farm income to intensify crop production. Uncertainty decreased this effect, but uncertain income streams may have increased next-year liquidity and, thus, next-year net crop income. Moreover, if the off-farm activity became the farmers' main interest, it no longer boosted net crop income.

The above implies that there will be a positive impact of nonfarm development on the development of agriculture under two conditions: i) nonfarm development involves an increase in the availability of relatively certain nonfarm employment with returns on labour above the agricultural wage rate; ii) nonfarm employment does not become the farmer's major concern. In other words, the nonfarm employment must be selectively available, and there will be a positive impact on the crop production of those farmers that succeed in getting a share. As nonfarm employment rises over time, the agricultural wage rate will go up to the level of the nonagricultural (shadow) wage rate, and the positive impact disappears. Alternatively, nonfarm employment becomes the main source of income for a part of the farm households, which also reverses the positive impact of nonfarm development on agricultural production. In the early stages of development when agriculture contains the mass of employment and economic resources, the conditions for stimulating agricultural development through the nonfarm economy are, however, available.

These findings shed new light on the study by Fan *et al* (2000), which considers the impact of different types of government expenditure on rural poverty and agricultural productivity growth in India. Fan *et al* found that in order to generate productivity growth in agriculture, the Indian government should give highest priority to additional investments in agricultural research and in rural roads. The latter is meaningful in light of the present study. Obviously, investment in roads increases the farmers' access to markets and decreases transportation costs of agricultural inputs and outputs. Fan *et al*, however, also showed that investment in roads boosts nonfarm employment. The present study suggests that this explains part of the positive impact of investment in roads on agricultural productivity.

Although this chapter indicates that income earned from public-works programmes does not affect same-year income from crop production, public-works programmes can raise net crop income indirectly. The introduction of public works may imply an increase in the savings capacity of the poorest farmers. The resulting additional liquidity at the beginning of the cropping season does have a significant positive impact on net crop income. Moreover, Chapter 6 indicates that the mere availability of public-works programmes in areas with high dry-season unemployment induces farmers to use more risky (and more profitable) production technologies. This is not the result of the income actually earned in these programmes, but the possibility to resort to public-works employment when crop yields are unexpectedly low.

8. DISCUSSION AND CONCLUSIONS

Continuous efforts are needed to stimulate stagnating agriculture in India's SAT. SAT agriculture provides a livelihood for over 250 million Indians, and this number is continuously increasing. The nonprimary sectors currently support only a small share of the population, and growth is not fast enough to increase this share rapidly. Consequently, agriculture has to absorb the bulk of population growth. Three factors are important in this respect: the demand for labour in agriculture, the biophysical sustainability of agricultural production, and crop income earned by smallholder households.

Smallholders are the major agricultural producers in India's SAT. Important determinants of their productive capacity are risk and credit constraints. Owing to the absence of sufficient long-term credit (and insurance), households have only a limited capacity to smooth consumption over time. On the other hand, empirical evidence on the availability of short-term production credit is mixed. Small farmers use little production credit, but this may be the result of prudence as well as credit constraints.

Most smallholders acquire a significant part of their income outside their own farm. Wage income from the daily labour market is the largest income source besides crop production. Other, less important, sources of off-farm income are the regular labour market, nonfarm self-employment, and remittances.

Income from these sources may have a strong impact on agricultural production decisions in a risk-prone environment with a strong seasonal agricultural production pattern like India's SAT. Off-farm activities are an important source of cash income, which can improve farm productivity if it is used to finance farm-input purchases or investment in agricultural assets. Moreover, off-farm income may help reduce the variance of overall household income and improve food security by allowing the household to buy food in cases of yield shortfalls. Households may then be able to increase the risk and profitability of their agricultural activities.

In India's SAT, where growing-season labour markets are well developed, not just off-farm income, but all labour income may affect the productivity of agriculture. Hired labour can be considered a perfect substitute for family labour. Own-farm employment, therefore, yields a return equal to off-farm employment: the market wage rate. Both employment types have equal liquidity and risk effects: own-farm employment means not having to spend a given amount of money, while wage employment implies earning a given amount of money.

The remainder of this section discusses the findings of this study regarding the impact of labour income and (other) off-farm income on crop production and income in India's SAT. Section 8.1 reviews the place of this study in the development economics literature. Section 8.2 summarises the major findings of the previous chapters, while section 8.3 explores the policy implication of these findings. 8.4 presents some final reflections on the findings of the study.

8.1. Off-farm income and the development economics literature

8.1.1. Farm-nonfarm linkages in the development economics literature

Farm-nonfarm linkages have inspired generations of development economists. Two general observations can be made: (i) the share of agriculture in a country's labour force and total output declines during the process of development; (ii) rapid agricultural growth needs to accompany or precede general economic growth. This process of transformation from an agricultural to an industrial economy is relatively well understood. Since the income elasticity of agricultural products is less than unity (Engel's law), the gross value of agricultural sales will grow less rapidly than gross domestic product. Moreover, a rapid growth in agricultural productivity is needed to foster incomes and to prevent a rise in the terms of trade in favour of agriculture (Timmer, 1988).

As early as the 1950s, Lewis designed a dual economy model describing the macro-level interactions that take place between the agricultural and the nonagricultural sector. The starting point of dual economy models is the coexistence of two sectors that are basically asymmetrical in terms of both product and organisational characteristics. On the one hand, there is a small modernising manufacturing sector, which accumulates capital and absorbs labour as needed. On the other hand, traditional agriculture employs little capital, relatively fixed inputs of land, and a pre-existing input of labour. The core of the development problem in this dual economy is the ability of the agricultural sector to yield sufficiently large surpluses and to preserve a sufficiently large part of such surpluses for productive investment in the nonagricultural sector. Moreover, in the process of development, low marginal product agricultural labour is reallocated to more productive employment elsewhere (Ranis, 1988).

More recently, development economics has shifted attention from these macro-processes to their micro-foundations. In a standard neo-classical setting, all individuals have the same information and do not face transaction costs. Markets for all goods exist, including markets for future goods and risks, and the only relevant institutions are markets and property rights (Hoff *et al.*, 1993). In developing countries, however, transportation and communication infrastructure are often rudimentary, legal systems are weak, and statutory and customary property rights systems may clash (Hoff *et al.*, 1993). Consequently, transaction costs and informational asymmetries play an important role in economic behaviour. Only when we understand the behaviour of economic agents in such an environment can we design appropriate policies to stimulate development.

For farm-nonfarm relations, this new approach implies a focus on the development of individual farm and nonfarm enterprises, and especially on the resource flows between the two types of undertakings. While both farm households and rural nonfarm enterprises have been extensively studied in isolation, attention to the nature of inter-enterprise resource flows has been limited. Important examples are the numerous studies by Reardon on farm-household income diversification (see references), but these mainly discuss theories and postulate hypotheses. The few empirical studies on the impact of off-farm income on farm income do not cover the impact of risk and seasonality on farm-nonfarm relations (Evans and Ngau, 1991; Woldehanna, 2000), which is the focus of the present study.

Although off-farm income is potentially very important for household risk management, most studies on farm-household risk behaviour focus on the role of savings and assets (Behrman *et al.*, 1997; Deaton, 1992a; Dercon, 1998; Rosenzweig and Binswanger, 1993; Rosenzweig and Wolpin, 1993). Risk may induce households to hold their wealth in assets that are relatively liquid, but not very productive. Moreover, if assets are used for consumption smoothing as well as production, the household asset endowment will be lower than the profit maximising level. Off-farm employment as an alternative risk-management tool could decrease the negative impact of risk on asset profitability, and therefore deserves substantial research attention.

8.1.2. Innovations

The focus of this study is on farm-nonfarm relations in the light of two important characteristics of SAT agriculture: risk and seasonality. Previous research has argued that these factors will strongly affect the impact of nonfarm income on farm production and income (Reardon, 1997). Farm households need to invest labour and other variable inputs in crop production months before the uncertain returns on this investment are realised. Off-farm income can facilitate this process in various ways. Off-farm income may increase cash availability during the pre-harvest season. This will decrease the effect of potential cash constraints or household prudence. Moreover, off-farm employment may offer households the possibility to increase the level of off-farm income when farm income is disappointingly low. This option will lower the variance of household income. Hence, it is not only the seasonality of crop production that shapes the farm-nonfarm relation, but also the seasonality of nonfarm activities.

Previous empirical research on the impact of off-farm income on farm production and income has largely ignored risk and seasonality. Agricultural seasonality is accounted for in that off-farm income is considered to alleviate cash constraints (Evans and Ngau, 1991; Reardon and Kelly, 1989; Woldehanna, 2000), but no distinction is made between different sources of off-farm income with different seasonal income flows. Moreover, previous empirical studies have not explicitly accounted for the stochastic nature of crop income.

In the present study, a two-stage model was developed that illustrates the diverse effects of wage income on crop production in an area with high production risk and well-functioning labour markets. The model reveals that in this situation no difference occurs between labour income earned on the family farm and that earned in the casual agricultural labour market. Both are certain and partly realised before the crop is harvested. Hence, the family labour endowment can be used to manage risk and liquidity constraints, irrespective of whether the household supplies labour to the market or not. The effects of risk, prudence, and credit constraints on inputs used in crop production are diverse. Credit constraints and prudence unambiguously lower input use. Risk may, however, increase as well as decrease input use, depending on the input at hand and the specific production environment. Previous research has overlooked this ambiguity in the impact of risk (Kanwar, 1999).

The model shows the importance of the seasonality of off-farm employment: households can use family labour for *ex ante* risk management as well as *ex post* income smoothing. *Ex ante* risk management involves an increase in labour supply in response to production risk, while *ex post* smoothing involves changes in household labour supply in response to unexpected variations in income from crop production. Previous research has considered both options in isolation, but not as a joint strategy. The empirical part of the present research indicates that ignoring the *ex ante* strategy and, to a lesser extent, the *ex post* strategy, does not much affect the results of studies on farm-household behaviour in India's SAT.

The measures utilised to demonstrate this are more precise than the risk measures used in previous studies. These studies used the standard deviation of production based on time series data as a measure of *ex ante* production risk (Kanwar, 1999; Saha, 1994). This measure includes historical information only and thus ignores a significant part of the information available to the farmer at planting: area to be planted, land quality, and actual weather. The Just-Pope two-stage method from the production literature, which is used in this study, allows inclusion of at least part of the farmer's nonhistorical information.

Previous studies on *ex post* income smoothing through adaptations in family labour supply are not very decisive (Kochar, 1995; Kochar, 1999). They base their conclusions on the impact of unanticipated income shocks on labour supply. Estimation of these shocks is tedious and imprecise. The model developed in this study shows that the demonstration of *ex post* risk coping through family labour supply does not require any shock estimates. If it is possible to single out harvest-stage labour supply, it is sufficient to determine the household's reaction to actual harvest-stage full income.

The study disentangles the effects of risk, prudence, and credit constraints on input use not only analytically, but also empirically. The latter is unusual. Risk aversion and credit constraints are unobservable, and asset ownership often serves as a proxy for both. Besides, it may be very difficult to distinguish the effects of liquidity constraints and prudence. The behaviour of a liquidity-constrained agent may be similar to the behaviour of an agent who can borrow as much as desired but who has a significant precautionary motive. What is more, in a consumer model that allows for both prudence and credit constraints, the effects of increased uncertainty and the effects of a more tightly binding budget constraint are identical (Browning and Lusardi, 1996).

The reason for the study's capacity to distinguish between risk and credit constraints is the potentially opposite impact of both factors on input use. The impact of production risk can be determined directly through inclusion of the expected variability of crop output in the estimation function. The coefficient of a proxy for risk aversion on input use must have the same sign as the coefficient for the risk measure. This knowledge often allows for determining whether short-term credit constraints are binding or not. Let us consider a case where risk increases the use of a specific input, *i.e.*, the impact of risk and credit constraints are opposite. Suppose that the use of this input is negatively affected by the household's endowment of illiquid assets. This must imply that risk aversion is more important for household behaviour than credit constraints are. Households with higher endowments of illiquid assets have more access to credit. Binding credit constraints would, therefore, cause a positive relation between asset ownership and input use instead of the negative relation observed.

Liquid assets are likely to have a larger impact on credit constraints and prudence than on risk aversion. Hence, no matter what the relation between risk and input use, the effect of liquid assets is expected to be positive, either because of prudence or because of credit constraints. If the coefficient for illiquid assets indicates that short-term credit constraints are of limited importance, a significant positive effect of liquid assets on input use results from prudence.

The model and the empirical estimates reveal how family labour affects crop production through its impact on income risk and liquidity. More family members mean potentially more labour income and thus higher liquidity and more income stability. If this is the case, the larger the family-labour endowment is, the smaller the effect of risk, prudence, and credit constraints on input use. Most previous research considers labour market imperfections as the only reason for a relation between family labour and the use of inputs. If labour markets are imperfect, more family labour will imply a greater use of labour in crop production. The model developed in this study shows that it is precisely the well-functioning of labour markets that can cause family labour to affect input use, and that the impact of family labour on labour used in crop production may be negative as well as positive.

Finally, the study looks into the direct effects of various sources of off-farm income on income from crop production. Casual wage employment was by far the main source of off-farm income in the study area. This seems to indicate that the effect of off-farm income equalled the effect of family labour described above. This is, however, not necessarily the case. Some households worked long hours, while others consumed large amounts of home time. Moreover, there were other (minor) sources of income besides casual wage income and crop production. Each income source may have had its own distinct effect on crop production.

Off-farm income sources differ with respect to capital requirements, timing, and riskiness and may, therefore, affect crop income differently. Timing of the activity relative to crop production determines its effects on liquidity and the potential competition for family labour, while the variability of income and the covariance with farm income controls the extent to which households can use the income source to manage risk. Although the literature recognises the importance of the nature of the off-farm income stream, these aspects have received little empirical scrutiny.

8.2. Crop production and off-farm income: Main findings

8.2.1. Risk and labour supply

Simulations based on regression results for two villages in India's SAT reveal that labour income was extremely important for the income stability of farm households. There were three stabilising effects of labour income: i) the presence of a certain flow of income; ii) *ex ante* risk management through labour supply; and iii) *ex post* income smoothing through adapting labour supply to actual crop production. *Ex ante* risk management implies that households will work long hours in order to guarantee a certain consumption floor, while *ex post* risk coping involves an increase in labour supply at the cost of home time when crop income turns out to be low.

The presence of a certain flow of labour income was most important for income stability as defined by the coefficient of variation. Compared to crop income alone, the coefficient of variation of crop and non-risk-induced labour income was about 75% lower for small farmers, 30% lower for medium farmers, and 10% lower for large farmers. Nevertheless, the intentional risk strategies were certainly not ineffective.

Ex post income smoothing significantly increased minimum income. As large-farm households experienced the highest yield losses, they made the most use of this strategy. This did not, however, hold for extremely wealthy farmers,[36] who had other means of stabilising income. A farm household's *ex post* smoothing capacity depends on the conditions of the dry-season labour market. Where there is high dry-season unemployment, the period in which farm households can work long hours to compensate for yield losses is short. The impact of *ex post* income smoothing through the labour market is, therefore, limited in this situation. When ample dry-season employment was available, farm households compensated 21% of the unexpected loss in crop income through *ex post* income smoothing.

Yield covariance hardly affected the household's capacity to smooth income *ex post.* Harvest wage rates were quite stable and only influenced to a very small extent by covariate yield shocks. This may come as a surprise to those who consider covariate weather variability the main source of production risk in the semi-arid tropics. However, weather and its impact differ between farmer's fields on a scale as small as a single village in India's SAT.

[36] Farm households cultivating more than 8 hectares of land in a rainfall-assured region with productive soils.

Only when the household's capacity to smooth income *ex post* was limited did they use family labour for *ex ante* risk management. The impact of this strategy on household income was largest for medium-farm households, who earned enough crop income to be significantly affected by production risk, and whose share of labour income was high enough to affect total income. A representative medium-farm household increased its average income by 8% and its minimum income by 32% through increased labour supply for *ex ante* risk management.

8.2.2. Input use

Farm households can manage risk not only by adapting family labour supply, but also by adapting the use of agricultural inputs. Depending on the production environment and the technology used, each input can increase as well as decrease the variability of crop production. If an input increases production risk, the risk-averse household will use this input below the level of profit maximisation. The opposite holds for risk-decreasing inputs. Farm households that are well able to manage risk, either through the ownership of large assets endowments or through large labour endowments in an environment with sufficient employment, will produce closer to the point of profit maximisation.

The empirical estimates show that the relation between risk and input use is diverse in India's SAT. In a relatively stable production environment, farmers used male labour to stabilise yields. Consequently, risk increased the use of male labour in crop production. The opposite holds in a rainfall-unassured area. Farmers were afraid to lose their labour investments in a bad year and applied less (male and female) labour when they faced higher risk. The impact of risk on fertiliser use was more uniform: output variability increased the use of fertilisers in both study villages. This implies that the village households considered fertilisers as risk-decreasing inputs. Perhaps surprisingly, the above household behaviour did not coincide with the technical relations found between input use and output variability. However, this deviation is not unique for the present study. The same was found for Texas farmers (SriRamaratnam, 1987).

The effects of the farmers' endowment of illiquid assets on input use confirm the above observations. Wealthier households, which were better able to smooth consumption, used less risk-decreasing fertilisers. Likewise, the impact of illiquid assets on labour use was opposite to that of production risk: if labour was considered to decrease risk, wealthier households used less labour in crop production and *vice versa*. In other words, more affluent households made less use of adaptations in input levels to manage risk. Depending on the characteristics of a specific input and the production environment, this resulted in either a positive or a negative impact of illiquid assets on the use of the respective input.

These findings imply that short-term credit constraints were not binding: binding credit constraints lead to a uniformly positive relation between illiquid assets, which are collateral to loans, and input use. The position of a household in the financial markets did, nevertheless, affect production behaviour. As the village households were prudent, risk decreased the willingness to borrow. Liquid asset holdings, therefore, had a positive impact on input use.

The risk management capacity of family labour was only large enough to affect input use when year-round employment was available. In this case, households with a larger labour endowment felt less need to adapt the use of crop labour and fertilisers to production risk. Well-functioning cropping-season labour markets were not sufficient to achieve this effect, unless the cropping season was sufficiently long. Moreover, given liquid asset holdings at the start of the cropping season, the impact of family labour on household liquidity was insufficient to affect household behaviour through prudence.

8.2.3. Net crop income and other household income sources

The conclusions from the previous section suggest that family labour will have a positive impact on crop income when there is year-round employment. In this situation, family labour is an important means of stabilising household income. More family members, therefore, implies that a household sacrifices less crop inputs for risk management. However, simulations indicate that a change in the number of family members would have had only a marginal impact on the total crop income of the survey households. Most of the estimated input elasticities of the mean and variance of production are low. A risk or otherwise induced change in input use, hence, translated into a much smaller change in the level and variability of output. Consequently, the simulated impact of family labour on crop income is negligible.

Despite this conclusion, actual labour income may still have had a significant impact on net crop income: some farmers worked longer hours than others did. Moreover, it would be interesting to gain insight into the specific impact on crop production of labour and other income from the nonfarm sector. When agriculture is relatively stagnant, development of the nonfarm sector could be a stimulus to agricultural production. One can analyse these issues by testing directly for the impact of different income sources on net crop income.

Empirical estimates show that the effect of noncrop income on crop income was diverse. The size and nature of the effects depended on the characteristics of the income flow.

Noncrop activities that required labour simultaneous to crop production and that had low returns on labour decreased net crop income. If the returns on noncrop activities were certain and high relative to the casual farm wage, households, however, simply substituted hired labour or capital for family labour. Moreover, they used part of the noncrop income to intensify crop production. Uncertainty decreased this effect. However, uncertain income streams may have increased next-year liquidity and thus next-year net crop income. Finally, if the nonfarm activity was the main source of interest of the farm household, income from this activity did not affect crop production.

8.3. Stimulating agricultural production through rural employment programmes

8.3.1. Off-farm employment and agricultural production

Farmers and agricultural labourers in India's SAT do not need to resort to nonfarm employment to compensate for periodical shortages of agricultural harvest-stage employment. As less than half of yield risk is covariate, fluctuations in aggregate labour demand and supply are small. Consequently, harvest wage rates and employment levels are relatively constant from year to year.

Yet, the availability of off-farm employment can significantly improve the economic security of farm households. Dry-season employment enhances the period in which households can increase their workload to compensate for low crop incomes. Besides, access to secure remunerative nonfarm activities increases the level and stability of household income. Hence, increased availability of off-farm income mostly leads to increased profitability of crop production. Risk-averse and prudent farmers produce closer to the level of profit maximisation if they have access to relatively certain and profitable off-farm activities. Only if the off-farm activity becomes their main interest does it not affect the profitability of their crop production. Otherwise, remunerative off-farm activities induce farmers to slightly increase the riskiness and profitability of their crop production.

In both study villages, increased risk-taking involved a decrease in the use of fertilisers since farmers considered fertilisers as risk-decreasing inputs. Given the low doses of fertilisers applied, it is surprising that farmers using fertilisers felt that they applied more than the profit-maximising level. Farmers are prudent as well as risk averse. In the absence of a relation between fertiliser use and production risk, prudent households will use less fertiliser than the profit-maximising level. Perhaps more importantly, the low fertiliser elasticity estimate from Chapter 6 indicates that actual returns on fertilisers were low due to inefficient application.

The effect of increased risk-taking on agricultural employment is ambiguous. The survey households worked fewer hours during the planting stage if they had sufficient possibilities to compensate yield losses through increased income-generating activities during the harvest-stage and dry season. This led to a slight decrease in involuntary unemployment. In contrast, the effect of increased risk-taking on the use of labour was undefined. Depending on the specific production environment at hand, higher yield risk involved either an increase or a decrease in the use of labour. The results for the two study villages suggest that increased farmer risk-taking is associated with an increase in labour use in areas with high production risk and a decrease in labour use in areas with moderate production risk.

8.3.2. Utilising employment policies to stimulate SAT agriculture

Technological innovation is a standard requirement for agricultural development. In line with this, Fan *et al* (2000) concluded that to increase agricultural productivity, the Indian government should give the highest priority to investment in research and development. Farmers must, however, be willing and able to adopt the new technologies. Whether they do so depends on their knowledge and the socio-economic environment. Of course, a new technology must be remunerative, but this is not the only criterion on which farm households base their decisions. Among other things, they account for the relative riskiness of different economic activities and for the amount of investment that these require.

Important for the adoption of new technologies is the distribution of information to the prospective users of the technology. Empirical estimates suggest that lack of knowledge has limited fertiliser use in the study villages. Older farmers from traditional farming families used more fertilisers than their fellow villagers did. The average efficiency of fertiliser use was low, however, which largely decreased the profitability of fertiliser use. Extension could lead to a significant increase in fertiliser use.

In addition to extension, governments can stimulate the adoption of technology through both price and other policies. Given the nonseparability of smallholders' production and consumption decisions, policies directed at nonprice factors may be most effective. Fertiliser subsidies, for example, have been a huge drain on government financial resources, while the current study indicates that the nitrogen price did not significantly affect nitrogen use. Moreover, the bulk of fertiliser subsidies goes to the more affluent farmers (Datt and

Sundaharam, 2000). Unless the general (market) infrastructure improves significantly, it is not likely that price policies will have much effect on agricultural production.

One aim of the present study was to assess the usefulness of employment policies for stimulating development of the agricultural sector. As explained above, the family labour endowment is an important tool for risk management. The higher the risk-absorbing capacity of family labour, the higher the willingness of farm households to engage in risky, but profitable technologies. This suggests that policies directed at the labour market will indirectly affect agricultural development. However, the current study provides only weak evidence for this relation. The family labour endowment of the survey households affected input use, but the resulting effect on crop income was negligible. On the other hand, the regressions demonstrate some significant direct effects of lucrative sources of nonfarm income on crop production.

Public-works programmes have a limited impact on agricultural production and income. Public-works programmes necessarily involve wage rates not higher than the casual wage rate paid in agriculture. Empirical estimates show that income earned in such activities does not increase the net income from crop production. On the other hand, the mere availability of public-works programmes in areas with a relatively short cropping season and low dry-season market employment induces farmers to use more risky production technologies. This change in technology is not the result of the income actually earned in government programmes, but the possibility to resort to public-works employment when crop yields are unexpectedly low. However, recall that this study could not demonstrate a significant effect of these changes on net crop income. Finally, the introduction of public works may imply an increase in the savings capacity of the poorest farmers. The resulting additional liquidity at the beginning of the cropping season will have a significant positive impact on net crop income.

Contrary to the introduction of public-works programmes, increased private nonfarm employment will have a positive impact on aggregate agricultural income in areas like India's SAT, where agriculture is by far the most important sector of the economy and labour markets function well. Farm households participating in remunerative nonfarm activities will partly or even more than compensate for the withdrawal of family labour from crop production by hiring labour in the village market. As long as the returns on labour in nonfarm employment exceed the casual agricultural wage rate, participation in nonfarm activities will lead to an increased profitability of crop production. In other words, the returns on nonfarm activities are not only nonfarm income but also an increase in net crop income. Increasing local agricultural income will, thus, be a side-effect of government programmes stimulating nonfarm employment. These programmes can involve stimulation of cottage industries or petty trade as well as small factories hiring in labour. However, the positive side-effect is only relevant for those fortunate households gaining access to activities with returns on labour above the common casual wage rate. The effect disappears when the agricultural wage rate comes to a par with the nonfarm wage rate.

Stimulation of nonfarm employment will not lead to a significant increase in the biophysical sustainability of agriculture through increased fertiliser use. Increased risk-taking leads to a decrease of fertiliser use. Public-works programmes, although valuable in their own right, are, therefore, not suitable to promoting smallholder fertiliser use. On the other hand, there might be a positive impact of remunerative nonfarm employment on fertiliser use through its impact on household liquidity. Still, extension seems much more effective in stimulatin g sustainability.

Summarising, the current study demonstrates a positive impact of nonfarm development on agricultural production and income, but — contrary to expectations and to assertions in previous studies — this impact is not very strong.[37] Moreover, the impact of nonfarm development on growth in the agricultural sector is likely to weaken even further over time. As nonfarm employment increases, the agricultural wage rate will go up to the level of the nonagricultural (shadow) wage rate. This breaks down the positive effect of nonfarm income on household economic security. Alternatively, nonfarm employment becomes the main source of income for some farm households, which also cancels out the positive impact of nonfarm development on agricultural production. Nevertheless, households earning substantial income from off-farm activities are not likely to withdraw completely from crop production. A recent visit to the village of Aurepalle revealed that households that earned much money through self-employment activities like toddy tapping and livestock herding have used part of this income to purchase land. Other research indicates that farm households in a village in North India's SAT have used nonfarm salaries to invest in irrigation (Parikh, 1996).

[37] Note that this conclusion is valid for India's SAT, where short-term credit is abundantly available. The impact of off-farm income on agricultural income is likely to be higher in Africa, where farmers lack access to all types of credit. In line with this, Woldehanna (2000) observes a positive impact of off-farm income on the use of variable inputs and crop income in the Tigray region in Ethiopia.

We can thus conclude that the possibility to improve farm production and income within the given setting is limited. An improvement in the general (market) infrastructure seems needed to decrease rural poverty substantially. Currently, the lack of good roads and an adequate chain of warehouses and transporters leads to a loss of about 20% of total agricultural output along the way from producer to consumer (Economist, 2001). In line with this observation, Fan *et al* (2000) suggested that investment in roads should be an integral part of any rural development policy. Their empirical analysis showed not only that roads stimulate both nonfarm employment and agricultural productivity, but also that public investment in roads leads to a larger decrease in rural poverty than investment in agricultural research, education, irrigation, soil and water conservation, power, rural development or health. Walker and Ryan (1990) argued that the economic growth potential of India's SAT lies mostly in high production potential areas like Kanzara. In the long run, households in areas with a low production potential, like Aurepalle, should migrate to the more well-endowed areas. Public-works programmes are required to absorb labour in the mean time. Unfortunately, the present study does not provide support for a more positive conclusion.

8.4. Reflections

The present research confirms that increasing dry-season employment will decrease the income volatility of farm households. This is, of course, not the only way to improve the economic security of these households. An obvious alternative would be the development of markets for long-term consumption credit. These markets are, however, plagued by information problems. Informal lenders are best able to master these problems. During the survey period, some informal consumption credit was available in Aurepalle, but not in Kanzara. Nevertheless, consumption volatility was highest in Aurepalle, as was income volatility. Moreover, the opening up of the village economy has led to a weakening of the informal credit market. It seems unlikely that government policies can alter this situation. Labour markets may be an indirect way to stimulate security, but at least they are transparent. Moreover, spending government funds on nonfarm employment programmes is justified in itself for reasons of absorbing the growth of the economically active population.

Despite the importance of labour income and (other) off-farm income to total income stability, the study indicates that the effects of these types of income on current crop income are not very large. However, during a recent field visit, farmers indicated that they had used income from nonfarm self-employment to purchase land. Several studies confirm the use of nonfarm income for agricultural investment. Savadogo *et al* (1994) found that nonfarm employment increases investment in animal traction, while Parikh and Thorbecke (1996) indicated that farmers use nonfarm salaries to invest in irrigation. Given these findings, it seems likely that off-farm income has more effect on agricultural investment than on current crop income. Future research should, therefore, focus on the more long-term relations between farm and nonfarm development.

Some other recent developments were observed during the field visit. Despite population growth, labour markets have tightened in both study villages. Kanzara households no longer resort to the public-works scheme for employment, as there is sufficient market employment available. This is not the case in Shirapur, the permanent ICRISAT village with limited agricultural development possibilities (see Chapter 2). In Shirapur, unemployment has increased significantly since the abolition of the public-works programme. In Aurepalle, many people migrate to the city during the dry season. At the same time, agricultural labour markets have tightened. Large landowners have problems hiring sufficient labour during peak seasons and adapt their crop technology accordingly: for example, some farmers sow their crops in squares instead of lines in order to facilitate interculturing and limit the need for (female) weeding labour.

In conclusion, it is worth stressing the paradox that this study presents. On the one hand, the survey farmers adapted input levels to exogenous production risk. On the other hand, these changes in input use had little effect on the variability of crop production. And if they did, they did not always do so in the direction that farmer behaviour suggests. Why then would farmers bother to adjust input use to risk? This behaviour seems difficult to reconcile with the standard economic assumption that farmers are at least boundedly rational. Farmers have generally cultivated the same set of crops on the same fields for years. Therefore, they are likely to know the relation between inputs and outputs. Would this be the case only for the average level of output and not for something as intangible as output variability? Alternatively, is there a relation between input use and yield variability that the estimated production function does not capture? This relation cannot lie in higher moments of the yield distribution: the yield distributions of the most commonly grown crop combinations approach normality. Finally, it is possible that a less restrictive functional form, such as the translog form, approximates the real production function more closely than the Cobb-Douglas form. However, the data set is too limited to accommodate these complex functions. Only additional research can elucidate the seemingly paradoxical behaviour of the survey households.

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APPENDIX 1. DERIVATION OF THE KUHN-TUCKER CONDITIONS

The following equations hold for the harvest stage:

$$U_{\ell_2} = w_2 U_{C_2}, \tag{A1.1}$$

$$g_{L_2} = \frac{w_2}{p}, \tag{A1.2}$$

$$F_2 = F_2\left(T_2, w_2, p, r, Q_1^*, B^*, Z\right), \tag{A1.3}$$

$$L_2 = L_2\left(Q_1^*, p, w_2\right), \tag{A1.4}$$

where:

$$Q_1 = f(L_1) + h(L_1)\gamma\varepsilon,\ \varepsilon \sim N(0,1). \tag{A1.5}$$

The Lagrangian for planting-stage decision problem is

$$\begin{aligned}\Im = {} & U[w_1(F_1 - L_1) + B, T_1 - F_1] + \rho EU[pg(f(L_1) + h(L_1)\gamma\varepsilon, L_2) \\ & + w_2(F_2 - L_2) - (1+r)B, T_2 - F_2; Z] + \lambda(B_m - B)\end{aligned}. \tag{A1.6}$$

The three decision variables are L_1, B, and F_1. Note that the choice of L_1 and B affects harvest-stage decisions regarding L_2 and F_2 (Eqs (A1.3)-(A1.5)). Moreover, the stochastic shock (ε) affects Q_1 and thus L_2 and F_2 (*ibid.*). Hence L_2 and F_2 are uncertain in the planting stage.

The first order condition for *labour demand* (L_1) can be derived as follows:

$$\begin{aligned}\frac{\delta\Im}{\delta L_1} = {} & -w_1 U_{C_1} + \rho E\left\{U_{C_2}\left[pg_{Q_1}\left(f_{L_1} + h_{L_1}\gamma\varepsilon\right) + pg_{L_2}L_{2,L_1} + w_2 F_{2,L_1} - w_2 L_{2,L_1}\right]\right. \\ & \left. - U_{\ell_2}F_{2,L_1}\right\} = 0\end{aligned}. \tag{A1.7a}$$

As $pg_{L_2} = w_2$ (Eq A1.2), this reduces to

$$-w_1 U_{C_1} + \rho E\left\{U_{C_2}\left[pg_{Q_1}f_{L_1} + pg_{Q_1}h_{L_1}\gamma\varepsilon + w_2 F_{2,L_1}\right] - U_{\ell_2}F_{2,L_1}\right\} = 0, \tag{A1.7b}$$

which can be rewritten as follows:

$$-w_1 U_{C_1} + \rho E\left(U_{C_2}pg_{Q_1}f_{L_1}\right) + \rho E\left(U_{C_2}pg_{Q_1}h_{L_1}\gamma\varepsilon\right) + \rho E\left(U_{C_2}w_2F_{2,L_1}\right) - \rho E\left(U_{\ell_2}F_{2,L_1}\right) = 0. \tag{A1.7c}$$

As $U_{\ell_2} = w_2 U_{C_2}$ (Eq A1.1), this reduces to

$$-w_1 U_{C_1} + \rho E\left(U_{C_2}pg_{Q_1}f_{L_1}\right) + \rho E\left(U_{C_2}pg_{Q_1}h_{L_1}\gamma\varepsilon\right) = 0. \tag{A1.7d}$$

This equals

$$-w_1 U_{C_1} + \rho p f_{L_1}E\left(U_{C_2}g_{Q_1}\right) + \rho p h_{L_1}\gamma E\left(U_{C_2}g_{Q_1}\varepsilon\right) = 0, \tag{A1.7e}$$

which can be rewritten as

$$f_{L_1} = \frac{w_1}{p} \frac{U_{C_1}}{\rho E(U_{C_2} g_{Q_1})} - h_{L_1} \gamma \frac{E(U_{C_2} g_{Q_1} \varepsilon)}{E(U_{C_2} g_{Q_1})}. \tag{A1.7f}$$

The first order condition for *borrowing* (B) is

$$\frac{\delta \mathfrak{L}}{\delta B} = U_{C_1} + \rho E U_{C_2}(w_2 F_{2,B} - (1+r)) - \rho E U_{\ell_2}(F_{2,B}) - \lambda = 0, \tag{A1.8a}$$

which can be rewritten as

$$U_{C_1} = \rho(1+r) E U_{C_2} - \rho E U_{C_2}(w_2 F_{2,B}) + \rho E U_{\ell_2}(F_{2,B}) + \lambda. \tag{A1.8b}$$

As $U_{\ell_2} = w_2 U_{C_2}$ (Eq A1.1), this reduces to

$$U_{C_1} = \rho(1+r) E U_{C_2} + \lambda. \tag{A1.8c}$$

Finally, the first order condition for *labour supply* is

$$\frac{\delta \mathfrak{L}}{\delta F_2} = w_1 U_{C_1} - U_{\ell_1} = 0 \ . \tag{A1.9}$$

APPENDIX 2. PRODUCTION RISK

Output variability can be determined using a two-step method developed by Just and Pope (1979). A third step gives an efficient estimate of crop production. Just and Pope define a production function that allows for separate effects of inputs on output and output variability. The specification includes two general functions—one that specifies the effects of inputs on the mean of output and another that specifies the effects of inputs on the variance of output. The function is given by

$$y = f(X) + h(X)\varepsilon, \quad E(\varepsilon) = 0, V(\varepsilon) = 1. \tag{A2.1}$$

Thus, $E(y)=f(X)$ and $V(y)=h^2(X)$.

We can rewrite A1. for observation t explicitly including the parameters of f and h as

$$y_i = f(X_i) + \varepsilon_i^*, \quad E(\varepsilon_i^*) = 0, E(\varepsilon_i^*\varepsilon_j^*) = 0 \textit{ for } i \neq j, \tag{A2.2}$$

where $\varepsilon^*_i=h(X_i,\beta)\varepsilon_i$. Supposing that both f and h follow a Cobb-Douglas form, we can now estimate α consistently with nonlinear least squares. Using the estimate of α, say $\hat{a}$, we can consistently (though not efficiently) estimate $f(X_i, \alpha)$ by $f(X_i, \hat{a})$. Thus ε^*_i can be estimated as follows:

$$\hat{e}^*_i = y - f(X_i, \hat{a}) . \tag{A2.3}$$

But note that

$$E\left[\left(\varepsilon_i^*\right)^2\right] = E\left[h^2(X_t, \beta)\varepsilon_t^2\right] = h^2(X_t\beta). \tag{A2.4}$$

This suggests the following regression equation:

$$\left(\varepsilon_i^*\right)^2 = h^2(X_i\beta)u_i . \tag{A2.5}$$

Hence, β can be estimated by regressing $ln|\hat{e}^*_i|$ on lnX_i using OLS. On the basis of this regression, one can easily determine $V(y)$.

Using this result, one can get attain asymptotic efficiency in estimation of α. The required procedure is to apply weighted least squares regression of y_i on X_i in eq (A2.2) with weights $h(X_i, \beta)$.

APPENDIX 3. INTERMEDIATE REGRESSION RESULTS

Table A3.1. First stage of the estimates for labour supply: full income (1000 Rs) (1979-1984)[a]

	Aurepalle (N=152)		Kanzara (N=124)	
	coefficient	standard error	coefficient	standard error
adults	1.44429***	0.29676	1.36881***	0.15246
cultivated area (ha)	1.74599***	0.39864	0.54152***	0.14449
cultivated area squared	-0.07690***	0.01940	-0.03795***	0.00912
land value (Rs/ha)	0.01118	0.02101	-0.01329	0.01288
irrigated/total cultivated	4.04987*	2.39523	-2.20003	1.91236
wage rate (Rs/day)	129.039***	41.4762	25.6722***	6.33100
bullock price (Rs/day)	-18.6070**	7.46423	-26.5866***	6.14043
inorganic nitrogen price (Rs/kg)	-2.77527***	1.05373	-0.56133***	0.14742
paddy price (Rs/kg)	-18.9328	12.3122		
cotton price (Rs/kg)			0.38048	2.41314
land ownership (ha)	-0.43608	0.32376	0.40870	0.33363
livestock (1000 Rs)	0.04687	0.10994	0.48271	0.43678
liquid assets (1000 Rs)	-0.12077	0.11054	0.10630	0.13051
year	-5.74112***	2.03297	-4.04830***	0.95546
Adjusted R^2	0.93		0.95	

Notes: [a] White/Heteroscedasticity corrected covariance matrices used.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A3.2. First stage of the estimates for labour use: share of irrigated area (1976-1984)[a]

	Aurepalle, N=240	
	coefficient	standard error
share of owned area irrigated	0.67054***	0.06749
bullock owned (yes=1)	0.00329	0.00983
previous-year share of cultivated area irrigated	0.07138	0.08619
ln(wage rate)	-0.01768	0.12946
ln(bullock price)	0.11335	0.10388
ln(nitrogen price)	-0.06167	0.08539
ln(castor price)	-0.00181	0.03240
ln(paddy price)	-0.37362*	0.21353
ln(greengram price)	0.05271**	0.02448
ln(liquid assets)	-0.00760	0.00989
ln(land owned)	-0.00374	0.00417
ln(livestock)	-0.00033	0.00287
ln(adults)	-0.00966	0.01916
year	0.01292	0.02144
dummy	-0.04639	0.03093
Adjusted R^2	0.82	

Notes: [a] White/Heteroscedasticity corrected covariance matrices used.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A3.3. First stage of the estimates for bullock use: ln(cultivated area) (1976-1984)[a]

	Kanzara (N=247)	
	coefficient	standard error
ln(previous-year cultivated area)	0.26049***	0.07967
bullock owned (yes=1)	0.28595***	0.09292
irrigated area/total area	-0.14458	0.25623
ln(wage rate)	-0.12214	0.53213
ln(bullock price)	-0.28007	0.40848
ln(nitrogen price)	0.22908	0.28144
ln(liquid assets)	0.03292	0.03412
ln(land owned)	0.58438***	0.11959
ln(livestock)	0.03783**	0.01864
ln(adults)	0.02489	0.08273
year	-0.01305	0.01960
Adjusted R^2	0.90	

Notes: [a] White/Heteroscedasticity corrected covariance matrices used. Output prices are included in the regression but not presented in the table.
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A3.4. First stage of the estimates for harvest labour use: ln(output value) (1976-1984)[a]

	Aurepalle (N=260)		Kanzara (N=271)	
	coefficient	standard error	coefficient	standard error
ln(expected output)	0.78766***	0.15658	0.55973***	0.11545
ln(inherent riskiness (γ))	0.33449	0.52508	0.74473***	0.23855
ln(wage)	0.58384***	0.16109	0.71812***	0.21273
ln(liquid assets)	0.04269	0.04438	0.00363	0.02995
ln(land owned)	0.01755	0.03651	0.10949	0.11618
ln(livestock)	-0.01895	0.05409	-0.00551	0.02124
ln(adults)	0.08400	0.12504	0.05975	0.10719
ln(cotton price)			-0.35203	0.21553
ln(castor price)	0.00995	0.29607		
ln(paddy price)	2.48331***	0.69792		
ln(sorghum price)	-0.36957	0.31325	0.22081	0.25150
ln(greengram price)	0.10405	0.17552	-0.45232**	0.18354
year	-0.11825***	0.03076	0.08516***	0.01946
Adjusted R^2	0.86		0.90	

Notes: [a] White/Heteroscedasticity corrected covariance matrices used.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table A3.5. First stage for crop income (1979-1984)

	Aurepalle Cultivated area (ha) (N=161)	Aurepalle irrigated area/total area (N=58)	Aurepalle Liquid assets (Rs) (N=161)	Kanzara Cultivated area (ha) (N=162)	Kanzara irrigated area/total area (N=38)	Kanzara Liquid assets (Rs) (N=162)
land owned (ha)	0.48145***	0.00044	-1325.49***	1.21254***	0.07813	2264.18***
	(0.11220)	(0.01548)	(224.645)	(0.19281)	(0.02646)	(508.337)
irrigated/total	2.58643	0.93041***	2619.47***	0.62144	0.49986	2288.63
	(1.76600)	(0.21650)	(678.246)	(0.94152)	(0.10732)	(2482.34)
bullocks	0.37205**	0.04377*	-222.202	0.64460***	-0.02122	-947.169*
	(0.14488)	(0.02356)	(289.881)	(0.18616)	(0.01098)	(490.807)
dairy animals	0.22529*	-0.01181	363.169	0.28905	-0.03749	-2679.40***
	(0.12624)	(0.01609)	(251.065)	(0.22239)	(0.01053)	(586.338)
young cattle	-0.00004	0.00002	0.43703			
	(0.00030)	(0.00004)	(0.59876)			
previous-year liquid assets	0.00002	0.00000	0.28791***	-0.00006**	-0.00000**	0.25399***
	(0.00003)	(0.00000)	(0.05939)	(0.00002)	(0.000000)	(0.07543)
previous-year self-employment	0.00000	0.00000	0.10663			
	(0.00013)	(0.00002)	(0.26590)			
previous-year nonfarm wages				-0.00018	0.000575***	-0.30345
				(0.00017)	(0.00013)	(0.44635)
previous-year regular wages				-0.00011	0.00002*	-0.01043
				(0.00013)	(0.00001)	(0.33838)
previous- year transfers				0.00031	-0.00000	-3.03425***
				(0.00022)	(0.00001)	(0.58356)
literate adults	0.00248	-0.07481	-695.512	-1.22479**	0.020511	1573.68
	(0.28970)	(0.11424)	(593.094)	(0.48962)	(0.04170)	(1290.91)
adults with sec. education				2.01957**	-0.01274	2631.86
				(0.91725)	(0.05735)	(2418.35)
women 25-44 yr	-0.99948***	0.19530**	-100.615	-0.27588	0.19768***	676.956
	(0.35715)	(0.06199)	(710.447)	(0.41146)	(0.04912)	(1084.84)
men 45-54 yr				0.56730	-0.14590*	2994.56*
				(0.63623)	(0.08340)	(1677.44)
adult men	-0.30441	0.12556	-60.0115	0.42656	-0.17973***	-1486.46
	(0.29551)	(0.10378)	(580.050)	(0.51994)	(0.04881)	(1370.83)
adult women	0.58695**	-0.01668	1535.05***	0.67270**	0.04862**	2066.40**
	(0.26225)	(0.10752)	(524.132)	(0.33411)	(0.02051)	(880.897)
constant	0.09205	-0.12847	7910.44***	-1.86654	-0.44723	-7845.91*
	(0.83551)	(0.27821)	(1675.96)	(1.61372)	(0.36972)	(4254.63)
Adjusted R^2	0.90	0.81	0.94	0.96	0.98	0.90

Notes: All monetary values are in 1983 prices.
*, ** and *** indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

APPENDIX 4. BACKGROUND INFORMATION FOR SIMULATIONS

Table A4.1. Exogenous prices

	Aurepalle	Kanzara
male planting wage rate (Rs/hr)	0.50	0.80
female planting wage rate (Rs/hr)	0.35	0.48
male harvesting wage rate (Rs/hr)	0.45	0.85
bullock price (Rs/hr)	1.30	2.22
nitrogen price (Rs/kg)	5.90	6.50
sorghum price (Rs/kg)	1.40	1.94
greengram price (Rs/kg)	3.79	3.99
castor price (Rs/kg)	3.46	
paddy price (Rs/kg)	1.42	
cotton price (Rs/kg)		5.40

Table A4.2. First stage estimates of full income for large Kanzara farmers (1979-1984)

N=26, full income in 1000 Rs	coefficient	standard error
adults	-4.65072**	1.77558
cultivated area (ha)	0.20510	0.46609
cultivated area squared	0.04988**	0.01897
land value (Rs/ha)	0.31340***	0.05456
irrigated/total cultivated	-7.20550*	3.62529
wage rate (Rs/hr)	228.756**	80.4807
bullock price (Rs/hr)	49.5394*	26.0649
inorganic nitrogen price (Rs/kg)	8.54405***	2.25583
land ownership (1000 Rs)	-0.00022***	0.00001
livestock (1000 Rs)	0.20433	0.24795
liquid assets (1000 Rs)	0.00022**	0.00001
year	-8.79358	6.35903
Adjusted R^2	0.97	

Notes: White/Heteroscedasticity corrected covariance matrices used.
All monetary values are in 1983 prices
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A4.3. Second stage estimates of labour supply for large Kanzara farmers (1979-1984)

N=26, labour supply in hrs	coefficient	standard error
full income (1000 Rs)	29.6169***	6.67643
liquid assets (1000 Rs)	-3.38723	2.67190
adults	198.108**	81.5344
wage (Rs/hr)	-2261.30**	845.269
land ownership (1000 Rs)	-0.00282**	0.00133
livestock (1000 Rs)	-14.6000	10.8357
year	160.353***	43.1540
Adjusted R^2	0.72	

Notes: White/Heteroscedasticity corrected covariance matrices used.
All monetary values are in 1983 prices
*, ** and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.

SUMMARY

Continuous efforts are needed to stimulate stagnating agriculture in India's SAT. SAT agriculture provides a livelihood for over 250 million Indians, and this number is continuously increasing. The nonprimary sectors currently support only a small share of the population, and growth is not fast enough to increase this share rapidly. Consequently, agriculture has to absorb the bulk of population growth. Three factors are important in this respect: the demand for labour in agriculture, the biophysical sustainability of agricultural production, and crop income earned by smallholder households.

The major agricultural producers in India's SAT are smallholders who acquire a significant part of their income outside their own farms. Wage income from the daily labour market is the largest income source besides crop production. Other, less important, sources of off-farm income are the regular labour market, nonfarm self-employment, and remittances. Income from these sources may have a strong impact on agricultural production decisions in a risk-plagued environment like India's SAT. Off-farm activities are an important source of cash income, which can improve farm productivity if it is used to finance farm-input purchase or investment in agricultural assets. Moreover, off-farm income may help reduce the variance of overall household income and improve food security by allowing the household to buy food in cases of yield shortfalls. Households may then be able to increase the riskiness and profitability of their agricultural activities.

The aim of the present study was to unravel the interactions between off-farm income and agricultural production in a high-risk environment. An analytical model was developed that brings to light the underlying decision processes of family labour supply and crop input use. Empirical estimates were used to test the relevance of the model and the impact of the different options and constraints. Moreover, the study determined the impact of off-farm income from different sources on income from crop production.

Chapter 2 presents the data and the methodological framework used: farm household modelling. The study used data from two villages in India's SAT, which were collected by resident ICRISAT investigators during the period 1975-1984. The villages represent two distinct agro-ecological zones. Aurepalle is located in the drought-prone district of Mahbubnagar, while Kanzara is situated in rainfall-assured Akola. Both the average productivity and the stability of yields were lower in Aurepalle than in Kanzara. The Kanzara labour market was buoyant due to the favourable production environment and the presence of

a public-works scheme. In Aurepalle, labour markets were competitive during the cropping season, but there was high unemployment during the dry season. Farm households in both villages were plagued by production risk and had limited capacity to smooth consumption from year to year.

While previous research has demonstrated that farm households use variation in family labour supply to smooth income, there is little evidence on the impact of the seasonal nature of agricultural production on farmers' labour supply. In **Chapter 3** a two-stage farm-household model is presented that provides insight into the seasonal determinants of labour supply under risk. A novel measure for production risk is used for the empirical analysis. This measure mimics the information available to the farmer more closely than the commonly used historical variance. Moreover, the analysis does not require tedious estimation of production shocks. Estimates for two Indian villages confirmed the use of family labour for *ex ante* risk management as well as *ex post* risk coping. These results have important implications for research on the cost of income uncertainty for farm households, which currently focuses on asset accumulation. Moreover, interventions in labour markets can significantly improve the economic security of farm households.

In order to absorb the increasing population of India's rural SAT, agricultural employment should expand continuously. Nonfarm employment policies are likely to affect agricultural employment, as the main agricultural employers, smallholders, are also important suppliers of market labour. These smallholders face high production risks and limited availability of credit. Wage income affects their capacity to cope with risk as well as their liquid asset holdings. Nevertheless, previous research has tended to ignore the interactions between wage income and farm labour use. Using the model presented in chapter 3, **Chapter 4** disentangles the ambiguous relations between risk, credit constraints, family labour and agricultural labour use. Empirical estimates for the two study villages show that, depending on the production environment, risk can increase as well as decrease labour use. However, there is no compelling evidence regarding short-term credit constraints. The estimates confirm the hypothesis that off-farm employment opportunities affect farm labour use, but the direction of the effect is ambiguous.

The possibility to use public works to stimulate farmers' fertiliser use in India's SAT was examined in **Chapter 5**. Inadequate replenishment of removed nutrients and organic matter has reduced fertility and increased erosion rates. Fertiliser use, along with other complementary measures, can help reverse this process, which ultimately leads to poverty, hunger, and further environmental degradation. In a high-risk environment like India's SAT, there may be a strong relation between off-farm income and smallholder fertiliser use. Farmers can use the main source of off-farm income, wage income, to manage risk as well as to finance inputs. Consequently, the introduction of public-works programmes in areas with high dry-season unemployment may affect fertiliser use. This study confirms the relevance of risk for decisions regarding fertiliser use in two Indian villages. Nevertheless, governments cannot use employment policies to stimulate fertiliser use. Public works even decreased fertiliser use in the setting of this study.

A simple two-stage simulation model based on the analytical model and the regression results from chapters 3 to 5 is described in **Chapter 6**. The simulation model consists of a production function, an income equation, and reduced form equations for the use of all major inputs and household labour supply. The results indicate that the risk-management strategies presented in Chapter 3 — ex ante risk management and ex post income smoothing through family labour supply — were effective in increasing minimum income. Much more important for income stability, however, was the flow of labour income that households earned independent of their risk preferences. The simulations also reveal that the impact of production risk on household income through changes in input use was small. Finally, harvest-wage variability due to yield covariance had little effect on household behaviour.

Chapter 7 takes a slightly different perspective than the remainder of the study and considers the impact of off-farm income from different sources on net crop income. While at the aggregate level of the regional economy, rising farm income may (or may not) spur nonfarm activities, at the level of the household, rising nonfarm income may stimulate advances in agriculture. Off-farm income can decrease the variability of total income and increase household liquidity. This can result in an increase in agricultural productivity. However, off-farm activities may also decrease the amount of resources used in agriculture. Previous research has shown that the impact of off-farm income on crop production and income depends on the technological and market environment. Chapter 7 shows the impact of timing, productivity, and riskiness of off-farm income on crop income. As these factors vary between various streams of income, distinct off-farm income sources affect crop income differently. Nonfarm development appears to stimulate crop production if it renders employment at a return higher than the casual agricultural wage rate but does not become the farmers' main interest.

In **Chapter 8**, the findings of the different chapters are combined and put into the perspective of development theory. Together, the chapters give a comprehensive picture of the role of labour endowment and off-farm income in rural development in India's SAT. This picture demonstrates how governments can stimulate agricultural and rural development through labour market interventions. Government programmes increasing private nonfarm employment are likely to lead to an increase in agricultural income. Public-works programmes have a smaller impact on agricultural production than private nonfarm employment has. The availability of public-works programmes in areas with a relatively short cropping season and low dry-season employment induces farmers to use production technologies that they perceive as more risky. Paradoxically, the present study could not demonstrate that this would lead to a change in the level and variability of crop income.

SAMENVATTING (SUMMARY IN DUTCH)

Bevordering van de stagnerende landbouw in India's semi-aride tropen (SAT) vergt voortdurende inspanning. SAT landbouw voorziet in het levensonderhoud van meer dan 250 miljoen Indiërs en dit aantal stijgt voortdurend. Slechts een klein deel van de bevolking verdient zijn inkomen in niet-primaire sectoren en deze sectoren groeien niet snel genoeg om dit aandeel op korte termijn te doen toenemen. De landbouw moet dus een groot deel van de bevolkingsgroei opvangen. In deze context zijn drie factoren belangrijk: de vraag naar arbeid voor landbouw, de biofysische duurzaamheid van landbouwproductie en het akkerbouwinkomen van kleine boeren.

Kleine boeren vormen de belangrijkste groep agrarische producenten in India's SAT. Deze boeren verdienen een aanzienlijk deel van hun inkomen buiten hun eigen bedrijf. Vooral arbeid als dagloner levert een aanzienlijke hoeveelheid inkomen. Andere, minder belangrijke bronnen van inkomsten zijn arbeid met een min of meer vast dienstverband, niet-agrarische activiteiten in eigen beheer en geldoverdracht van familie en vrienden. Het inkomen uit deze bronnen kan een belangrijke invloed hebben op de agrarische productie in een risicovolle omgeving, zoals India's SAT. Activiteiten buiten het boerenbedrijf zijn een belangrijke bron van liquide middelen. Deze extra liquiditeit kan de landbouwproductiviteit verhogen als ze wordt gebruikt om gewasinputs te financieren of om te investeren in agrarische activa. Inkomen van buiten het boerenbedrijf kan bovendien de stabiliteit van het totale huishoudinkomen verhogen. Daarnaast kan dit inkomen de voedselzekerheid verbeteren, omdat het de mogelijkheid schept voedsel te kopen als de eigen oogst laag is. Dit alles zou huishoudens in staat kunnen stellen het risico en de winstgevendheid van hun agrarische activiteiten te verhogen.

Het doel van de huidige studie was het analyseren van de interacties tussen inkomen van buiten het boerenbedrijf en agrarische productie in een omgeving met een hoog productierisico. Er wordt een analytisch model ontwikkeld dat de onderliggende beslissingsprocessen betreffende het aanbod van familie-arbeid en het gebruik van gewasinputs laat zien. De relevantie van het model en de invloed van verschillen mogelijkheden en beperkingen van het boerenhuishouden worden getest door middel van empirische schattingen. Bovendien wordt de specifieke invloed van verschillende inkomensbronnen buiten het boerenbedrijf op het gewasinkomen bepaald.

Hoofdstuk 2 presenteert de data en het gebruikte methodologische kader: modelering van agrarische huishoudens. Er worden data gebruikt uit twee dorpen in India's SAT tijdens de periode 1975-1984. De data zijn verzameld door onderzoekers van ICRISAT, die gedurende het onderzoek in de desbetreffende dorpen woonden. De dorpen vertegenwoordigen twee verschillende agro-ecologische zones. Aurepalle ligt in het droogtegevoelige district Mahbubnagar, Kanzara in het relatief regenrijke Akola. Zowel de gemiddelde productiviteit als de stabiliteit van de gewasproductie was lager in Aurepalle dan in Kanzara. Dankzij de gunstige productieomstandigheden en de aanwezigheid van openbare werken was de werkloosheid laag in Kanzara. De arbeidsmarkt in Aurepalle was concurrerend tijdens het productieseizoen, maar er was hoge werkloosheid tijdens de droge tijd. Boerenhuishoudens in beide dorpen werden geplaagd door productierisico's en konden de verschillen in jaarinkomen die hierdoor ontstonden maar ten dele compenseren door bijvoorbeeld te lenen of het eigen vermogen te variëren.

Eerder onderzoek heeft aangetoond dat boerenhuishoudens variatie in gewerkte uren gebruiken om hun inkomen te stabliseren. Er is echter weinig bewijs van de invloed van het seizoensmatige karakter van landbouwproductie op het arbeidsaanbod van boerenhuishoudens. In **Hoofdstuk 3** wordt een tweefase landbouwhuishoudmodel ontwikkeld. Dit model verschaft inzicht in de seizoensafhankelijke factoren die bepalend zijn voor het arbeidsaanbod in een omgeving met een hoog productierisico. In de empirische analyse wordt gebruikt gemaakt van een nieuwe maat voor productierisico. Deze maat benadert het risico zoals de boer dat ervaart beter dan de meestal gebruikte historische variantie. Bovendien vereist de empirische analyse geen schatting van de productieschok. De resultaten voor de twee Indiase dorpen laten zien dat de boeren familiearbeid gebruikten voor zowel *ex ante* risicomanagement als *ex post* risicobeheersing. Dit resultaat heeft belangrijke gevolgen voor onderzoek naar de kosten van inkomensonzekerheid voor boerenhuishoudens, dat zich momenteel richt op de accumulatie van bezit. Bovendien laat deze studie zien dat arbeidsmarktinterventies de economische zekerheid van boerenhuishoudens significant kunnen verbeteren.

Agrarische werkgelegenheid zou continu moeten groeien om de groeiende bevolking van India's rurale SAT op te vangen. De belangrijkste agrarische werkgevers, kleine boeren, zijn ook de belangrijkste aanbieders op de arbeidsmarkt. Deze kleine boeren worden geconfronteerd met hoge productierisico's en een beperkte beschikbaarheid van krediet. Arbeidsloon beïnvloedt zowel hun mogelijkheden om met risico om te gaan als hun liquide middelen. Dit betekent dat niet-agrarische werkgelegenheidsbeleid naar alle waarschijnlijkheid de agrarische werkgelegenheid beïnvloedt. Desondanks laat het meeste onderzoek de interacties tussen arbeidsloon en het gebruik van arbeid in de gewasproductie buiten beschouwing. In **Hoofdstuk 4** wordt de tweeslachtige relatie tussen risico, kredietbeperkingen, familiearbeid en agrarisch arbeidsgebruik geanalyseerd. Dit gebeurt aan de hand van het model van Hoofdstuk 3. Empirische schattingen voor de twee studiedorpen laten zien aan dat, afhankelijk van de productieomgeving, risico tot een toe- of een afname van het gebruik van arbeid leidt. Er is echter geen overtuigend bewijs voor een beperkte beschikbaarheid van kort krediet. De schattingen bevestigen de hypothese dat werkgelegenheid buiten het eigen bedrijf het agrarische arbeidsgebruik beinvloedt, maar de richting van het effect is hangt af van de locale omstandigheden.

In **Hoofdstuk 5** wordt de mogelijkheid onderzocht om het kunstmestgebruik van boeren in India's SAT te stimuleren met openbare werken. Onvoldoende aanvulling van nutriënten en organisch materiaal heeft geleid tot erosie en een afname van de bodemvruchtbaarheid. Kunstmestgebruik kan, in combinatie met andere maatregelen, leiden tot een omkering van dit proces, dat uiteindelijk leidt tot armoede, honger en verdere degradatie van het milieu. In een risicovolle omgeving, zoals India's SAT, kan inkomen van buiten het boerenbedrijf een grote invloed hebben op het gebruik van kunstmest. Kleine boeren kunnen de belangrijkste bron van niet-landbouwinkomen, de arbeidsmarkt, gebruiken voor zowel risicomanagement als inputfinanciering. De introductie van openbare werken in de droge tijd kan derhalve het kunstmestgebruik beïnvloeden in gebieden met een hoge seizoenswerkloosheid. De huidige studie toont aan dat risico invloed hed op de beslissingen betreffende kunstmestgebruik in de twee bestudeerde dorpen. Desondanks kan werkgelegenheids-beleid niet worden aangewend om het kunstmestgebruik te stimuleren. Onder de onderzochte omstandigheden leiden publieke werken zelfs tot een lager kunstmestgebruik.

Hoofdstuk 6 beschrijft een eenvoudig tweefase simulatiemodel gebaseerd op het analytische model uit Hoofdstuk 3 en de regressieresultaten van Hoofdstuk 3 tot en met 5. Het simulatiemodel bestaat uit een productiefunctie, een inkomensvergelijking en herleidevormvergelijkingen voor het gebruik van alle belangrijke inputs en het arbeidsaanbod van het boerengezin. Simulaties met dit model laten zien dat de risicomanagementstrategieën zoals gepresenteerd in Hoofdstuk 3 —*ex ante* risicomanagement en *ex post* risicobeheersing door familiearbeid— effectief waren in het verhogen van het minimuminkomen. Veel belangrijker voor inkomensstabiliteit was echter het arbeidsinkomen dat huishoudens verdienden onafhankelijk van hun risicovoorkeuren. De simulaties laten bovendien zien dat de invloed van productierisico op huishoudinkomen door verandering in inputgebruik klein was. Tenslotte hadden onverwachte variaties in de loonvoet tijdens het oogstseizoen nauwelijks invloed op het gedrag van de huishoudens.

In **Hoofdstuk** 7 wordt uitgegaan uit van een iets ander perspectief dan de rest van de studie. De invloed van inkomen van verschillende bronnen buiten het boerenbedrijf op het netto gewasinkomen wordt geanalyseerd. Op geaggregeerd niveau kan extra agrarisch inkomen leiden tot een toename van de niet-agrarische activiteiten in de regio. Daarentegen kan op huishoudniveau een toename van het inkomen van buiten het eigen bedrijf de agrarische productie stimuleren. Inkomen van buiten de landbouw kan echter ook een daling veroorzaken van het gebruik van hulpbronnen in de landbouw. Eerder onderzoek heeft aangetoond dat de invloed van niet-akkerbouwinkomen op gewasproductie en -inkomen afhangt van de technologische en marktomgeving waarin de boer opereert. Hoofdstuk 7 laat de invloed van timing, productiviteit en risico van niet-gewasinkomen op gewasinkomen zien. Omdat deze factoren variëren tussen de verschillende inkomensstromen, hebben verschillende bronnen van niet-gewasinkomen een verschillend effect op gewasinkomen. Niet-agrarische ontwikkeling blijkt gewasproductie te stimuleren als het voorziet in werkgelegenheid met een hogere opbrengst dan het agrarische dagloon, onder voorbehoud dat de boer akkerbouw als zijn hoofdactiviteit blijft zien.

In **Hoofdstuk 8** worden de bevindingen van de verschillende hoofdstukken gecombineerd en worden ze geplaatst in het perspectief van ontwikkelingstheorie. Tezamen geven de hoofdstukken een uitgebreid beeld van de rol van familearbeid en inkomen van buiten het boerenbedrijf in de ontwikkeling van India's SAT. Dit beeld laat zien hoe via arbeidsmarktinterventies de landbouw en de ontwikkeling van het platteland gestimuleerd kunnen worden. Het stimuleren van private niet-agrarische werkgelegenheid zal in veel gevallen leiden tot een toename van het gewasinkomen. Openbare werken hebben een kleinere invloed op de landbouw dan private niet-agrarische werkgelegenheid. In gebieden met een kort groeiseizoen en lage werkgelegenheid gedurende het droge seizoen, zullen boeren na de introductie van openbare werken overgaan op technieken die zij als meer risicovol ervaren. Vreemd genoeg kan de huidige studie niet bewijzen dat een dergelijke gedragswijziging ook werkelijk invloed heeft op het niveau en de variabiliteit van het landbouwinkomen.

CURICULUM VITAE

Marieke Marrit van den Berg was born on April 15, 1971 in Geldrop, the Netherlands. She attended Wageningen University from 1989 till 1995, when she obtained *ingenieur*'s diplomas in Tropical Land Use and Rural Development Studies, with majors in Land Evaluation and Development Economics and minors in agronomy and GIS. She received the C.T. de Wit prize for her thesis entitled '*The Economic Efficiency of Agrarian Production Cooperatives in Comayagua, Honduras*'.

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