PRODUCTION RISK AND COMMERCIALIZATION OF AGRICULTURE IN RWANDA: IMPLICATIONS FOR HOUSEHOLD LABOUR SUPPLY AND FOOD SECURITY*

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November 30, 1993

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* This work was conducted under a CIDA (Canadian International Development Agency) Grant to the International Food Policy Research Institute (IFPRI). The views expressed here are those of the author and do not necessarily reflect the views of the organizations involved.

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A Thesis

Presented to

The Faculty of Graduate Studies

of

The University of Guelph

by

KENE EZEMENARI

In partial fulfillment of requirements

for the degree of

Doctor of Philosophy

November 4, 1993

ABSTRACT

PRODUCTION RISK AND INCREASED COMMERCIALIZATION OF AGRICULTURE IN RWANDA: IMPLICATIONS FOR HOUSEHOLD LABOUR SUPPLY AND FOOD SECURITY

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University of Guelph, 1993

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This dissertation examines the effect of production risk on the resource allocation and consumption decisions of rural households in Rwanda. The implications of this for the implementation of policies designed to increase the marketed surplus of households in the study area are examined. Two policy instruments are examined: a floor price policy and reduction of market transaction costs which encourage subsistence production by these households.

The study develops a framework which incorporates risk into a static model of the agricultural household. The wedge between prices received and paid for food staples by households is explicitly modelled in order to account for the effect of market transaction costs. Households are categorized according to whether they are net sellers or net buyers of food. Two measures of welfare are used to assess the impact of risk on rural households in Rwanda: nutritional status of children in the household and the risk premium associated with the production risks faced by these households. Labour supply is examined as a principle means of managing the risks faced by rural households. Specifically, the effect of risk on the labour supply decisions of males and females in the household are examined.

Results from the production side show that there is a significant level of production risk in the area. It also shows that households are significantly risk averse and therefore associate a significant cost with risk. It is found that when the household's ability to manage risk through household labour supply and allocation is taken into account the welfare cost associated with production risk is lower. Imposing a floor price on basic staples increases the labour supply of women (who are primarily the producers of food crops in Rwanda) in absolute and relative terms as compared to male labour. Risk does not have a significant impact on household labour supply but, does have a stronger and significant impact on female labour allocation (between farm and non-farm activities) than it does on male labour allocation. The removal of risk increases the food consumption of all household types. It is also found that a reduction in market transaction costs leads to greater gains by all households in terms of household food consumption and the nutritional status of children than a floor price policy.

ACKNOWLEDGEMENTS

I feel fortunate in having had the opportunity to pursue my studies at the University of Guelph and would like to thank the staff and friends who contributed to my learning experience at Guelph. I would also like to thank those individuals who contributed to my research both at Guelph and out on the 'field' in Washington D.C.:

I gratefully acknowledge IFPRI (International Food Policy Research Institute) for granting me access to the data set used in the current study. I am thankful to Joachim von Braun my 'field' supervisor whose probing questions and comments were instrumental in shaping the framework for this dissertation. The patience and perseverance exhibited by my committee members (Alfonse Weersink, Wayne Howard, Brian Ferguson, and Truman Phillips) as they read through endless drafts of the dissertation was much appreciated. I particularly would like to thank Truman Phillips for his support and guidance. I would also like to thank the members of the examining committee (Bill Braithwaite, Erna van Duren, and John Strauss) for their time and comments.

I am also indebted to CIDA (Canadian International Development Agency) for the funding which made it possible to conduct this research. I especially would like to thank Iain MacGillivray for his patience and understanding.

I would also like to thank those individuals who contributed to the research process in a more informal manner: Howdy Bouis, Tesfaye Teklu, Sumiter Broca, Clemen Gehlhar for their stimulating discussions and insights; Lawrence Haddad for his references and papers lent to me which I promise to return ---someday; my friends in

Washington who helped me in keeping the whole 'dissertating' experience in perspective (Clemen Gehlhar, Christine Peña, Bjørg Colding) --you guys were right they are not out to get me!; Daphne Taylor for her continual friendship and moral support throughout my Ph.D. program --I don't believe its finally over!; my family in Boston for believing in me and being there for me; and last but not least to Okon Akiba whose love and encouragement (in lieu of those 'brainstorming' sessions) helped in producing the final draft.

I dedicate this dissertation to my parents.

TABLE OF CONTENTS

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

LIST OF TABLES

LIST OF TABLES, continued

LIST OF FIGURES

CHAPTER ONE
PRODUCTION RISK AND THE CONSUMPTION OF AGRICULTURAL HOUSEHOLDS

1.1 Introduction

Numerous studies in the past have examined the effect of increased commercialization on food security (Kennedy and Cogill 1987; von Braun et. al. 1991; Bouis and Haddad 1990). The consensus is that increased commercialization leads to increased incomes (when correctly implemented). However, it is unclear what effect increased commercialization has on food consumption and nutritional status. There has been much debate in the literature as to whether increased commercialization improves or worsens food security (Dewey 1981; Flueret and Fleuret 1980). This question will be re-examined in this study with the consideration that risk may be a major determinant of the household's level of commercialization.

Consideration of the effect of risk within the above context is important for several reasons. First, rural food markets are poorly integrated within most less developed countries. Second, this poor integration of rural markets adds to the problem of semi-subsistent production. A low level of integration among related markets is primarily a consequence of poor roads, ineffective marketing institutions and infrastructure, and highly inefficient means of disseminating market information (Timmer 1983). The result of these isolated markets is that prices are regionally determined and individual producers' output are highly correlated to regional output. Add to this under-developed credit markets and poor storage facilities, and the result is that production risks arising from weather shocks and pests have a direct impact on consumption, so that, household production decisions depend on household consumption decisions. This leads to wider swings within a region of food availability over time and wider differences in distribution across regions. The resulting high transaction costs arising out of these poorly integrated markets cause the persistence of semi-subsistent farming (Goetz 1992). This leads to low food availability and therefore a low level of food security and nutritional status.

Those studies which have explored the linkages between increased commercialization, and food consumption and nutritional status have not explicitly incorporated risk into the analysis. In addition, most studies dealing with risk and food insecurity have assumed separability between consumption and production decisions and therefore have concentrated strictly on the production effects of risk without examining the effect on consumption. This gap in the literature provides the rationale for the current study.

This study will examine the effect of production risk on consumption and the implications for increased commercialization as a means of improving the food security of agricultural households in Rwanda. In the process, the effect of risk on the resource allocation decisions of the agricultural household will be examined.

1.2 The need to Incorporate Consumption and Production Decisions in a Common Framework

In modelling the decision process of the agricultural household in developing countries, a framework is needed which explicitly takes into account the semi-subsistent nature of these households. This semi-subsistent nature is characterized by the tendency of these households to consume most of what they produce and that their decision of how much to produce may also depend on their consumption requirements.

Past studies which have examined the issue of agricultural risk and its relationship to food insecurity depended primarily on safety-first decision criteria and lexicographic preferences. Programming models are used in modelling these decision criteria which are comprised of maximax and minimax decision rules. The maximax decision rule considers only the most favourable outcome of each action choice while ignoring all other possibilities. Whereas, the minimax rule orders action choices on the basis of only the least favourable outcome of each possible choice (Fleisher and Robison). The safety-first framework is used to analyze production decisions given the probability of occurence of some critical consumption level. This critical consumption level is usually arbitrarily chosen. Therefore, this framework does not allow one to model the simultaneous determination of production and consumption decisions by the agricultural household.

1.3 The Conceptual Framework

The conceptual framework for the current study will be based on that outlined by Pinstrup-Andersen (1981 and 1985). Within this framework, commercialization affects food consumption and nutritional status (at the household level) through its effect on food availability and intra-household food distribution.[1] Food availability at the household level is determined by the household's ability and desire to acquire food. The ability to acquire food depends on the purchasing power of the household (Sen 1981) and on its ability to grow its own food. If food prices are higher than the imputed price for own production due to marketing costs (or underdeveloped markets) then expansion of cash crop production may erode real incomes and lower food consumption. The household's ability to grow its own food will depend on its access to factors of production such as labour, land, credit, improved inputs and fertilizer. Increased commercialization may lead to competition between food versus cash crops for the factors of production. Resources may be diverted away from food to cash crop production and this may increase the household's exposure to market risk because of increased participation in the market and yield risk because of less diversification in crops and plots.

A household's desire to acquire food depends on: intra-household income and budget-control[2]; income source and composition; access to goods other than staple foods;

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[1] Pinstrup-Andersen outlines the process through which commercialization affects intra-household food distribution.

[2] Studies by Kumar (1978) and Guyer (1980) show that the marginal propensity to consume food out of income may differ according to gender and source of income.

time constraints on individuals within the household; and the level of nutritional knowledge of the person responsible for food preparation.

Risk will be incorporated into this framework by examining its effect on the household's ability and desire to acquire food. In considering the household's ability to acquire food this study will concentrate on the effect of yield and output price risk on production and income and how this translates to food consumption levels, and nutritional status of the household. In the presence of underdeveloped insurance markets, the semi-subsistent nature of the agricultural household implies a higher interdependence between production and consumption decisions (Singh, Squire and Strauss). Production risk would be expected to have a more profound effect on the allocation of resources to production and on consumption decisions. This is because, in the presence of risk, with underdeveloped credit markets, households concerned with food security will take into account consumption requirements in making production decisions (Singh, Squire and Strauss 1986).

In order to mitigate the effect of production risk on consumption, households must rely more heavily on other means at their disposal (given underdeveloped insurance markets) for managing risk. Alderman and Paxson (1992) divide these strategies into two categories: risk management and risk coping strategies. Risk management strategies are strategies that anticipate the effects of risk (ex ante meausres) and try to prevent it. Risk coping strategies are those that are used (ex post measures) after the damage or loss has occured. Among risk management strategies which reduce the variability of income are: the use of risk reducing inputs, crop/plot diversification, allocation of family labour to off-farm occupations, and migration of family members. Risk coping strateties, which are strategies used to smooth consumption involve: saving/dissaving (credit and storage) which spread the effects of risk forward through time and risk sharing in the form of crop insurance, futures and forward contracts, share tenancy, and labour contracts which spread risk across households at a point in time. In addition to these strategies one could also add the exploitation of the correlation between prices and production by net seller households (as mentioned above).

The effect of risk on the desire to acquire food will be explored through its effect on the labour allocation and supply of males and females and their relative productivity under production risk. Particular attention will be paid to women's labour supply and allocation decisions which is important in the Rwandan situation. Women hold the major responsibility for food production and preparation. Their labour decisions will affect food consumption through its effect on income (Popkin 1980). Food consumption levels and the time women have available for nurturing activities will then impact on nutritional status.

The means used by the household to mitigate the effects of risk will affect the degree to which production risk affects consumption for different household types. In addition, the level of risk and risk attitudes will affect the degree to which risk affects the household's allocation decisions and therefore consumption (food security) and nutritional status. The level of risk will add to the level of transaction costs faced by the agricultural household in the presence of underdeveloped insurance markets. The pattern of risk attitudes will have implications for the level of food security. For example, a pattern of decreasing risk aversion with respect to wealth means that for the same level of risk, households with low income face higher risk premiums. Therefore, uninsured income (or lack of access to credit facilities) leads to increased income inequality and therefore adverse consequences for food security especially for the poorest households. This means that policies whose goal is to encourage improved incomes particularly for the poor, through commercialization and technological change should consider these intervening factors in order to ensure proper targeting and thereby circumvent any potential unintentional effects.

1.4 Research Objectives and Outline

In the past, the government of Rwanda has attempted to encourage increased comercialization through a floor price policy. There have been several problems associated with the implementation of this policy. First, there is the problem of targetting. The government, in implementing this policy, assumed that all agricultrual households were net sellers of food products. However, the majority of agricultural households in Rwanda are net buyers of food products. Therefore, a floor price policy only serves to exacerbate the semi-subsistent pattern of production (Loveridge 1988). Net buyer households are forced to rely more on their own production to maintain household consumption levels. This constrains the level of market demand and as a result, the level of marketed surplus that could be achieved by net seller households. The existence of production risk exacerbates this situation, particularly for net buyer households, who are forced to rely more on the market when production is low. The result is a lower price response by these semi-subsistent households.

Analysis of the way in which production risk may affect household consumption, nutritional status, and resource allocation will shed more light on ways households may be aided in improving and maintaining their level of food security. The study will be conducted within a static framework which explicitly models the production and consumption decisions of households in Rwanda. Two major questions will guide the research:

1) What is the extent and nature of agricultural risks faced by agricultural households in the study area?

2) What is the impact of the existence of this risk on consumption and nutrition decisions in the household? In particular, does risk alter the time allocation decision of women and what is the implication of this for women's value of time and therefore nutritional status of children in the household?

In order to address the research questions it will first be necessary to categorize households according to their market orientation. The level of production risk faced by agricultural households in Rwanda and the attitudes of these households towards this risk will be examined. The terms technological change, risk and commercialization will be defined and measured as follows: Technological change in the Giciye commune of Rwanda involves single crop potato production with modern inputs as opposed to potato production with traditional inputs. The econometric methodology outlined by Antle (1987;1983) will be used in deriving an objective measure of production risk and the risk attitudes of these households. Commercialization refers to an increased integration of the household into the rural market economy. This integration can occur through inputs to farming, increased sales from output from farming and increased income from non-agricultural sources. von Braun, de Haen and Blanken (1991) define measures that capture these aspects of commercialization which will be used in the current study. Concept 1, measures the extent to which farm households consume out of aggregate agricultural production. It is defined as the ratio of non-marketed produce to the total value of production. Concept 2, measures subsistence orientation out of consumption. It is the ratio of the value of goods consumed out of home production relative to total consumption value of the household. The last measure to be used in the current study is based on the conceptual framework from which concepts 1 and 2 of von Braun, de Haen and Blanken are based. This is a measure of subsistence orientation from the input side and may also be interpreted as a measure of the degree of dispersion of modern production techniques. This measure is defined as the ratio of the value of home produced variable inputs to production to the total value of variable inputs.

This study will attempt to increase understanding of the interaction of variables which determine food insecurity and also suggest further indicators and targeting mechanisms of food insecurity which are based on how risk effects the household's decision process. These indicators would be useful not only in predicting households which are likely to become food insecure in the future, but also in improved implemention of commercialization policies. The study will proceed as follows: Chapter 2 will provide a brief over view of the study ares, Chapter 3 will review the current literature on risk preference estimation. Chapter 4 will outline the theoretical model to be used in the analysis. Chapter 5 will outline the empirical model in terms of the econometric models estimated and the methdology used in generating the simulation results. Chapter 6 will describe the data source and the econometric results. Chapter 7 will discuss the simulation results and policy implications. Finally, Chapter 8 will summarize the results and outline areas for future study.

CHAPTER TWO
OVERVIEW OF THE STUDY AREA

2.1 Background

Rwanda is a land locked country located in the east central part of Africa. With a population density of 254 per square kilometer, it is one of the most densely populated countries in Africa (Scott 1988). As of 1988, 7% of its 6.76 million inhabitants resided in the urban areas. Agriculture represents 40% of GDP and employs 90% of the population.

International trade is limited because of transportation costs (von Braun et.al. 1991). Official exports represent 8 - 9% of GNP with the major export crop coffee comprising 75% - 85%, and tea the next major export crop 10%-15%. Food comprises less than 10% of exports. Official imports are made up mainly of consumer goods, fuel, lubricants, equipment, and raw materials. Informal trade with neighbouring countries consists of palm oil, beans, and coffee, on the import side, consumer goods, and white potatoes on the export side (Loveridge 1988; Ngirumwami 1992).

Within Rwanda, regional trade is limited by high transaction costs and transport costs that are high relative to product prices (Loveridge 1988:119-120). The result is that agricultural households must rely on their own production in order to ensure a steady source of food. The degree and pattern of consumption from home production is tied to the seasonality of production and production risks faced by the household. Loverdige (1988:99) states that in times of high yields these households consume more from home production, and in times of poor yields consume less from home production. Therefore, when rural supply is high (demand is low) and vice versa. A small negative shock to aggregate production may translate to a large reduction in marketed supply for a given agricultural household and an increase in demand, thus leading to a low level of food availability. Inadequate storage facilities also contribute to the problem of low food availability. Storage is highly risky in Rwanda. Variation in prices in peak periods is quite large from year to year and few merchants engage in interseasonal storage of food crops (Loveridge 1988:95). These problems contribute to an increase in the level of food insecurity especially for the poorest households. A recent example has been the regional outbreaks of weather induced famine in 1989-90 which has contributed to the declining trend in production (Minot 1992). The declining trend has been driven by increasing population pressure on limited resources coupled with farming systems which have not adapted to the higher population density.

The Rwandan farming system is a traditional one that is characterized by smallholders and rainfed irrigation geared toward semi-subsistent production. The majority of farmers have limited land and financial resources. Their ability to purchase more of the most important inputs (labour and seed) is therefore limited (Scott 1988). Also, for tuber crops, such as potatoes, disease and shortage of quality seeds are a major constraint to produciton. In addition, increased population pressure causes a decrease in the fallow period and an increased cropping of marginal land and deforestation. In a national survey conducted by Loveridge (1988:45), Rwandan farmers ranked soil fertility and land area as the most important constraints. Labour constraints and inadequate rain were ranked as the next most important constraints to production. The farmers' ranking of constraints to production also varied by region within the country. In Gisenyi prefecture (the site of the current study) where population density is higher than in other areas of the country, land was cited as the major constraint to production. Whereas, in Kibungo, a relatively sparsely populated area labour was the major constraint. Given the farming system, constraints to production and production risks faced by agricultural households, the government has chosen price policy as the main instrument to stimulate production for market and improve food security.

2.2 Rwandan Food Policy

The government's main objective has been to increase food self-sufficiency and improve rural income. In the past, Rwanda has been able to maintain its growth rate in total food supply by expanding total cultivated area. However, in recent years the population growth rate appears to be outstripping the rate of increase in the food supply as the area cultivated in the country quickly reaches its capacity. Average farm size has fallen to the point that over half of the more than one million agricultural households in Rwanda cultivate less than one hectare (Loveridge:8; Dialogue 1986).

Before 1986, the government operated under an indicative pricing scheme. The government established optimal price levels and tried to move the market towards these "targets" through market operations of the parastatal OPROVIA (Office National pour le Developpement et la Commercialisation des Produits Vivriers et des Produits Animaux). The purpose of the government set "target" price levels was to provide a reference point from which farmers could bargain with merchants, thereby discouraging excessive profits to merchants. However, this indicative pricing did little to raise prices received by the producers (Loveridge:8; Dialogue).

Since 1986, the policy instrument the government has used in an attempt to stimulate production and increase incomes in the rural areas has been floor prices for important crops such as beans, sorghum, potatoes, and maize. However, this instrument has been ineffective in maintaining producer prices at or above the official price for several reasons: an inappropriate method of determining producer prices; the government instrument used in enforcing prices (OPROVIA) is too weak; and unintended adverse effects on the pattern of income distribution[1]. A significant proportion of agricultural households are net buyers of some of the above major food crops. If the floor price policy had been effective, it would have led to adverse effects for those households that fluctuate between self-sufficiency and buying from the market when production is low (marginal buyers), and those households that are net purchasers of food stuff (permanent buyers). These households would have been forced to become more self-sufficient and yet they have less access to productive assets and land.

Revision of the floor price policy in 1988 has been effective in maintaining producer prices above official levels. However, the impact of this policy on food security in the rural areas is expected to be bleak. A government policy of minimum price for food crops would benefit the seller households and not the buyer households

[1] See Loveridge (1988:143-151) and Dialogue (1986:58-64) for an indepth discussion of these factors which has led to ineffective price fixing by the Rwandan government.

who would tend to be more susceptible to food insecurity. Aggregate food availability remains low because prices are high which causes buyer households to become relatively more self-sufficient. This leads to low aggregate demand and low marketed surplus by seller households. The low elasticity of aggregate supply for food crops in Rwanda reported in Minot (1992:228) supports this.[2] Floor prices also have implications for women's labour supply. In Rwanda, women are primarily responsible for the cultivation of the major food staples. Floor prices may lead to increased labour supply for women (particularly for the buyer households). This would have implications for household food security and nutritional status which will be explored in later chapters.

Production risk in the area is caused by pests, disease, and weather. In addition, inability of households to hire enough labour during the peak season to take advantage of favourable weather conditions may also exacerbate the level of production risk (Franzel et.al.). This production risk would translate into consumption risk depending on the degree of subsistence of the agricultural household (de Janvry and Sadoulet). From the above discussion it can be seen that floor prices would increase the degree of subsistence of buyer households thereby making them more susceptible to consumption risk. The degree to which this occurs depends on the household's ability to diversify the consumption risk (arising out of production or income risk) it faces. In LDCs households have various ways of smoothing their consumption in the face of the production the risks that they face. Among these are: alternate income sources, savings

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[2] Minot reports supply elasticity estimated from other sources that range from .396 for white potatoes (which is a commercial food crop in Rwanda) to .094 for beans.

and dissavings, storage of food, crop and plot diversification and risk sharing. Off-farm labour supply is particularly important in smoothing consumption risk in Rwanda. Given the riskiness of production, at the margin, a household faced with an equivalent return to labour between farm and off-farm labour will choose to work off-farm because the wage rate is less uncertain. Since most households in Rwanda, cultivate less than 1 hectare their strategy has been to : 1) produce primarily for home consumption; and 2) look for part-time work off-farm to complement their farm income (GTZ:20).

The above discussion may explain why farmers in Rwanda continue to grow food crops despite higher returns to capital and labour of growing cash crops (von Braun and Kennedy 1986). In the commune of Giciye, situated in the northwestern part of Rwanda, an average of two-thirds of agricultural production is consumed on the farm (von Braun et. al. 1991). The result is that the full gains from specialization and trade are not realized. Low incomes continue to persist because of subsistence farming as a response to risk in the face of increasing envirnomental stress and underdeveloped markets. Thus, if government's goal is to promote commercialization as a means of improving food security it is important to understand how the households' consumption decisions are affected by risk. This understanding would lead to the identification of policy instruments and targetting mechanisms that will ensure food security while promoting increases in incomes through commercialization and technological adoption.

2.3 Main Characteristics of Giciye Commune

The data for the current research was collected from Giciye commune which is located in the Gisenyi prefecture (district) in the northwestern part of Rwanda. Giciye is one of 143 communes of Rwanda. A commune is defined as the lowest governmental and administrative unit, with a bourgmestre as the official government representative. The commune is further divided into secteurs which are divided into cellules. A cellule consists of roughly 100 families. The total area of Giciye commune is 185 square kilometers with 120 suitable for agricultural production. The remainder is part of the Gishwati forest. In 1984, the population of Giciye commune was estimated at 52,236 persons with a growth rate of 4% (Csete 1989).

The area belongs to the agroecological zone of the Central Zaire-Nile Divide. It is characterized by high altitudes (more than 2,000 meters), low average annual temperature (15 degree celcius), with an average annual precipitation of 1,300 millimeters which follows a bimodal pattern. In the study area, the altitude varies from 1,500 to 3,000 meters with most of the area at 2,000 meters. There are four climatic seasons: a long rainy season from mid-February to late May; a long dry season from the end of May to mid-September; a short rainy season from mid-September to early or mid-December; and a short dry season until mid-February. The zone has very steep slopes of 30-40 degrees which cause severe soil erosion.

2.3.1 Crop Calendar

The agricultural calendar in the region is summarized for the major subsistent crops in Table 2.1. Sweet potatos are harvested continually through the season in the high altitude areas. They may be stored in the ground and harvested as required by the household (Loveridge 1988; Csete 1989). In the swamp areas sweet potatoes are cultivated during the long dry season of June-August. Peas, beans and white potatoes are harvested twice a year (once in February and another harvest mid July to September). Sorghum and maize are harvested once at the beginning of the calendar year. The area is characterized by extensive intercropping. Maize or sorghum may be intercropped with potatoes, beans and peas.

2.3.2 Local Food Markets

Only one main road crosses the commune of Giciye and leads to the inter-regional market - Mukamira. Giciye commune has three markets of various size and importance which take place twice a week at : Gasiza, Jomba, and Vunga. Kabaya is another important market place situated at the border of Giciye and Gaseke. Jomba and Gasiza are classified as relatively small local markets comprised mainly of farmers themselves as sellers and buyers. Kabaya and Vunga are classified as markets of medium to high importance in the interregional exchange of agricultural produce. Kabaya, Gasiza and Mukamira have markets two days a week on different days. Most foodstuffs are transported to market in baskets on the heads of farm family members. A small percentage of goods is brought to market on pick-up trucks owned by private merchants (Csete 1989).

The important commercial food crop in the area is white potatoes cultivated with improved inputs in the Gishwati potato scheme located in the Gishwati Forest (see Figure 2.1). The Gishwati Forest project was designed to tear down the remaining natural forest in order to plant more commercial varieties of trees and open up the remaining for organized grazing. In 1981-82, the project began to allow farmers to grow only white potatoes in the region. The development of new varieties by the national potato program (PNAP) in 1984 with the assistance of the International Potato Center boosted the marketed surplus of white potatoes in the region. The new varieties were of a shorter vegetative cycle and allowed farmers three harvests a year of potatoes. The pattern of nearly continuous harvests from the expanded region of cultivation in the forest encouraged larger-scale merchants to begin sending trucks to the forest on a daily basis for transport of potatoes to Mukamira and other market centers (Csete 1989).

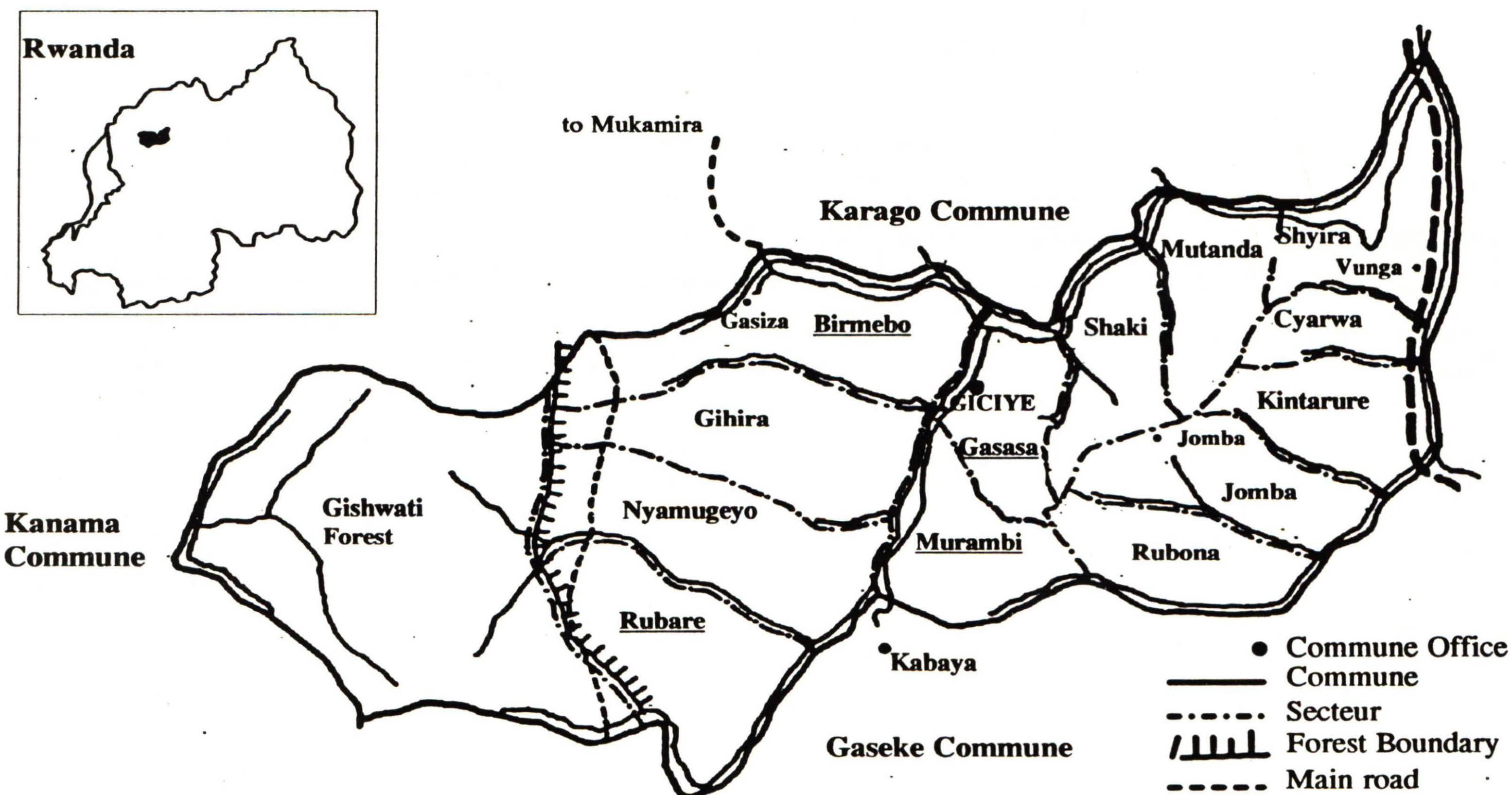
The degree of production risk may be discerned from the movement of prices since production and price levels are highly negatively correlated (Loveridge; Damez 1986:36). Figure 2.2 shows the seasonality in price for the major staples in the area for Mukamira and Gasiza. Beans and maize show relatively less price movement than potato, sorghum and sweet potatoes. The price movements for Mukamira show that potatoes have a high degree of price variation or market risk. Beans display the least price variation. The implications of this risk for different households will be examined in the chapters to follow.

Table 2.2 summarizes certain socio-economic variables by household type for the survey sample. The table shows that there are differences between these households in terms of access to factors of production and food availability in the household. There is also a difference in the hours worked by women in the different households. Women appear to work hardest among the marginal buyer households. These households are the most subsistence orientated and do not perform very well in meeting average daily household food requirements. In addition, the high level of female labour supply may have adverse consequences for nutritional status of children in these households. Net seller households do the best in terms of meeting daily requirements. These households are also quite highly subsistence orientated but have more access to productive factors. Households which switch from buying one period to selling the next period (buyer/seller households) perform relatively better than buyer and marginal seller households in terms of meeting their daily requirements. These households appear to behave as speculators that buy when prices are low in order to sell when prices are high (Damez: 35).

2.4 Summary

This chapter has provided an overview of the key factors in the study area which is characterized by significant level of production risk and isolated rural markets with low food availability. Production risk affects the different household types depending on their level of subsistence orientation and their ability to smooth their consumption. The remaining chapters will examine this process in detail.

Figure 2.1: Map of Giciye Commune in the Prefecture of Gisenyi



Note: The underlined secteur names are those of the four secteurs selected for the study.

Table 2.1: Crop Calendar for the Major Food Staples in Giciye (Medium and High Altitude)

Crop/Month	Janua	Febru	March	April	May	June	July	August	Septem	October	Novemb	Decemb
Potato	■■■■	■■			■■■■	■■■■	■■■■	■■■■		■■	■■■■	■■■■
Peas	■■■■	■■		■■■■	■■■■	■■■■	■■■■			■■	■■■■	■■■■
Sweet Potato												
Single Stand	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■
Mixed						■■■■	■■■■	■■■■	■■■■	■■■■	■■	
Maize	■■■■					■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■
Sorghum	■■■■	■■■■				■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■
Cassava	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■
Beans	■■■■				■■	■■■■	■■■■	■■■■		■■■■	■■■■	■■■■
Wheat			■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■			

Note:The cultivation period is represented by ■, which refers to one quarter of the month or one week.

Table 2.2: Summary of Socio-economic Variables by Household Types

	Net buyer	Marginal buyer	Net seller	Marginal seller	Buyer/ seller
Percentage (out of 200 households)	44	11	13	8	24
Ave. Size of Household (capita)	5.72	4.76	5.88	4.87	5.75
Total Land Area (ha.)	.58	.85	1.04	.85	.77
Man-Land Ratio	13.3	9.43	8.82	9.37	9.98
Subsistence[3] orientation in income	46.04	82.67	65.23	59.05	51.01
Dependency Ratio	38.31	30.15	35.02	26.8	38.32
Calories Available/adult equivalent/day	2296	2282	2600	2127	2472
Percentage of Households meeting 80% of calorie requirements	46	44	54	47	54
Hours/day spent by Women on[4]:					
Income generating work	5.74	7.13	7.18	6.98	5.64
Non-income generating work	3.92	4.44	2.79	3.21	4.24
Per capita Expenditure (FRw/capita)	2843	3212	3532	3494	2870

[3] This definition is the proportion of subsistence production out of total total income for the household. Dependency Ratio refers to the proportion of children (less than 14 years) in the household.

[4] Income generating work involves: farm work and off-farm labour. Non-income-generating work involves: housework, fetching water, wood etc.

Figure 2.2A: Seasonal Variation in Staple Food Prices

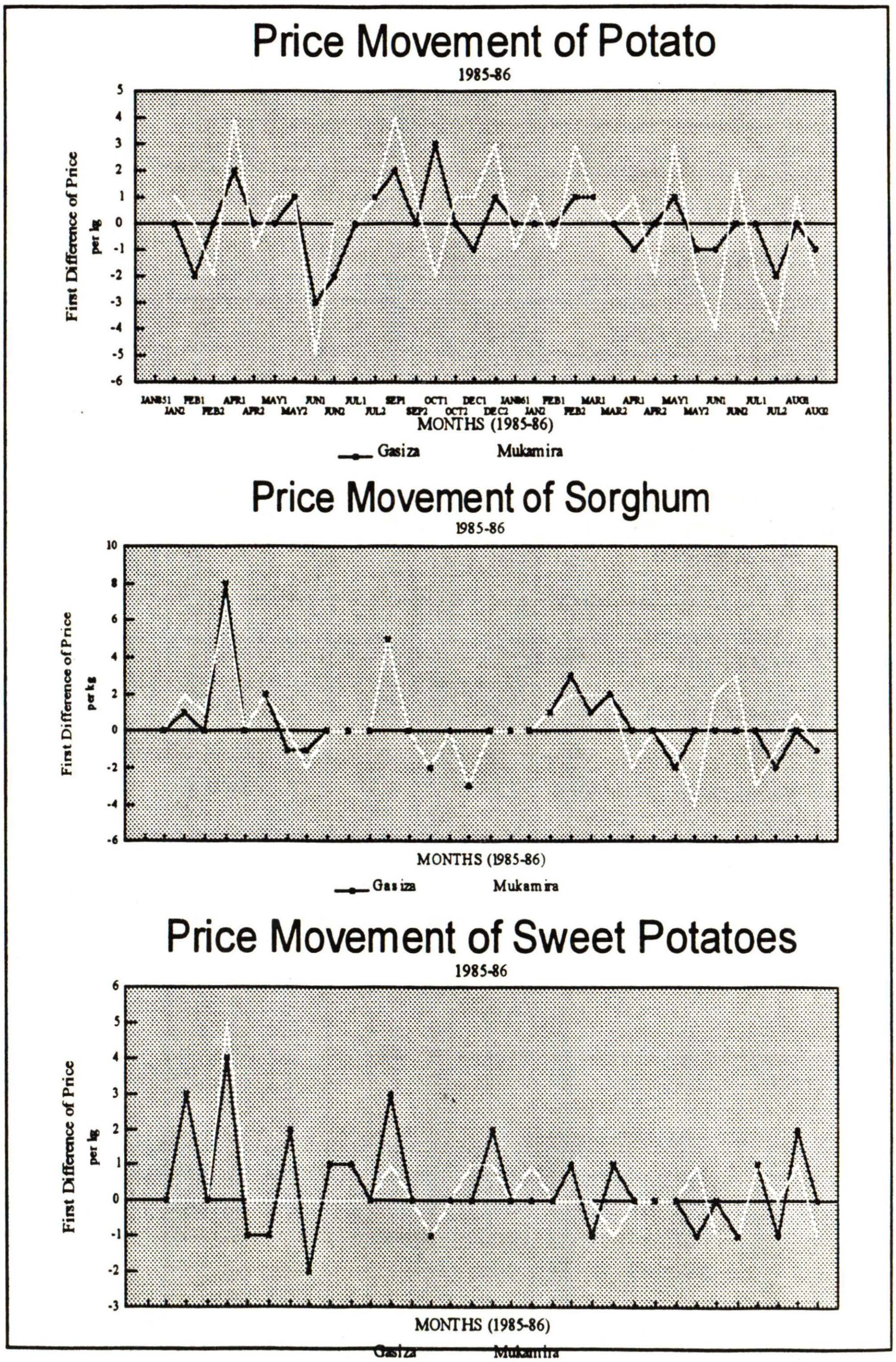
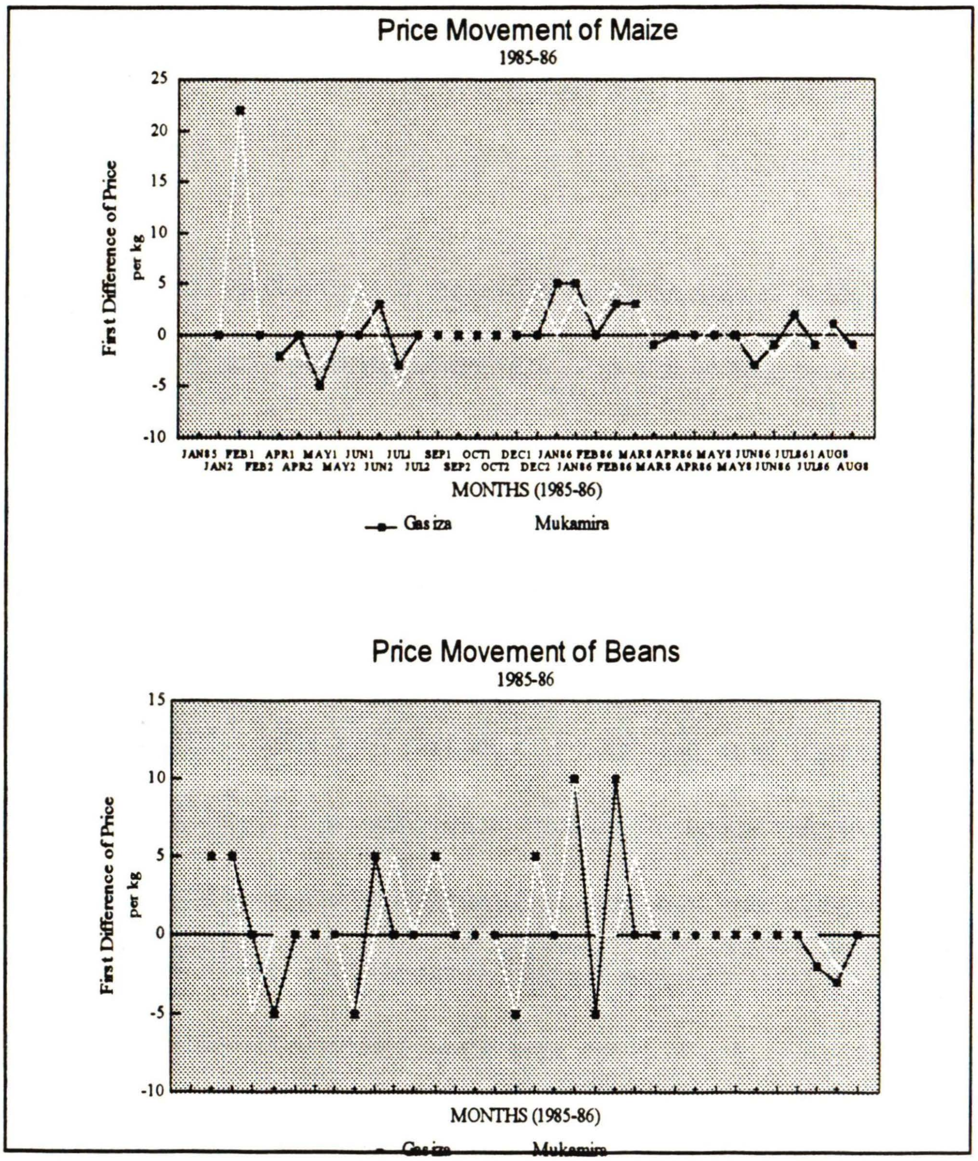


Figure 2.2B: Seasonal Variation in Staple Food Prices



CHAPTER THREE
RISK, RISK ATTITUDES, AND AGRICULTURAL HOUSEHOLDS

3.1 Introduction

The objective of this chapter is to summarize the implications of production risks for the food security of semi-subsistent households. This will be done by summarizing past studies which have attempted to analyze the problem of risks faced by agricultural households and the implications for household food security. The studies summarized highlight three key factors that determine how risk affects household food security. These factors are: the degree of risk faced by the household, the risk attitude of the household and how this varies with changes in wealth, and most importantly the household's ability to smooth its consumption or diversify the income risks it faces. In the process of reviewing these studies methodological issues arise concerning the cross-sectional measurement of risk, risk aversion and demand analysis.

The chapter begins by first reviewing the basic theory of risk, risk attitudes and their measurement. Afterwards, some empirical studies will be reviewed along with papers that have attempted to incorporate risk into an agricultural household framework.

3.2 Measuring Risk

3.2.1 Theoretical issues

Robison and Barry (1987) define risky events as uncertain events to which past empirical data allows one to assign probabilities of occurence (objective) or to which agents involved in decision making are able to assign their belief as to likely probabilities of occurence based on information available to them (subjective). Based on this definition of risk, a natural measure of risk which is found in the literature involves some satistical measure of variability or some estimate of a probability density funciton. However, two important theoretical issues arise in measuring risk: 1) How does one measure increases in risk?; 2) does an increase in risk imply reduced welfare? The natural measure of an increase in risk of a variable would be to increase the degree of dispersion/variance keeping the mean constant. However, Rothschild and Stiglitz (1970 and 1971) show that it may not always be the case that a decrease in the variance of a variable keeping the mean of the distribution constant (mean preserving spread) will lead to increased expected utility. This condition can only hold if the probability density function of the variable is fully represented by the mean and variance (as in the normal distribution); or if the utility function is concave with respect to wealth (Newberry and Stiglitz 1981; Rothschild and Stiglitz 1971). Concavity of the utility function implies risk aversion while convexity implies risk loving attitudes. Thus, the second condition involves solving the problem of ranking distributions for risk-averse agents. As Figure 3.1 shows, a mean preserving increase in the varaince of profit implies a decline in the expected value of a concave utility function; and an increase in expected utility of a convex utility function. Rothschild and Stiglitz (1970 and 1971) use this result to proove that a full ordering of risky alternatives can be achieved through a mean preserving spread.

3.2.2 Empirical Measures of Risk

In the literature measures of production and income risk involve measures of the variability of the random variable over time. This measure is simple to estimate with aggregate time-series data. However, in the case of cross-sectional data or panel data with short time series it is not as clear how one should derive a measure of risk. This problem has been tackled in various ways in the literature. One way has been the inclusion of experimental data and cross sectional data used by Roumasset (1976). Roumasset also used experimental data to measure yield risk. Risk was measured from the probability density function of rice yields for various levels of nitrogen and solar radiation. However, he notes that using experimental data to model actual behaviour may pose certain problems (Roumasset 1976:119). The sources of variation in controlled experiments are quite different from those on farmers' fields. Therefore experimental data does not represent actual conditions on farmers' fields and may not always explain actual behaviour. In addition, controlled measures are used to deliberately reduce variation in yield estimates. These measures have limited generality for the farm level.

In order to address these problems, Roumasset combines expermimental data with a cross-section of actual farm data. The production function estimated from experimental data is used as the risk-free production level. Actual farm data are used to estimate the probability of damage across all farms. These two estimations are then used to derive the expected production function for a given state of the world. This method is highly data demanding and abstracts from the actual decision process of farmers in that deviations from the mean is based on some 'abstract ideal' of average or expected yield for the household.

Another method employed in the literature is the 'permanent income' method examples of which include Wolpin (1982), Ram (1992) and Bhalla (1979). These studies use the instrumental variable technique to estimate income risk which is then used in testing the permanent income hypothesis. Among examples of instruments used by this method are: age, schooling, education, family size, variables on rainfall and agroclimatic conditions, seasonal and regional dummies. The predicted value from this instrumental variable regression is used as an estimate for permanent income. The residual from the actual income level and the predicted value provides a measure of income risk. In the Wolpin case in particular, the use of historical weather data to instrument income is intuitively appealing since it was applied to agricultural households in India. However, the above techniques abstract from the household production technology which would be an important influence in the income stream of the agricultural household.[1]

Finally, the methodology developed by Just and Pope (1978) which was extended by Antle is based on the time-series and cross-sectional variation in production. Antle used a flexible moment based approach to estimate the higher moments of production in

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1 See also the review by Alderman and Paxson which cite studies that have used exogenous shocks (such as the amount of rainfall) to predict production risk. This measure was not available for the current study.

a manner which does not restrict input decisions in terms of how the higher moments are affected. This methodology is employed in the current study. First, because only data on actual farms as opposed to experimental data is available for the study area. Second, unlike Just and Pope, Antle's methodology does not restrict the effect inputs may have on the higher moments of production. Therefore, these effects can be estimated from observed behaviour where deviations from the mean for each household is relative to its own expected production level and household characteristics. One criticism of the Antle approach is that it makes use of the heteroscedascity present in production across households. The problem here is that heteroscedascitiy is usually assumed to depict specification error. The Antle approach makes use of this heteroscedasticity. However, there is no means for determining whether the heteroscedasticity is due to specification error or differences across households arising from the variation in household characteristics. The current study circumvents this problem, as does Antle, by specifing a functional form which may be interpreted as a Taylor series expansion of inputs about the observed level of output. The current study makes use of the Antle methodology assuming that it represents a Taylor series expansion about the mean level of production (as assumed by Antle). Aside from the above criticism, the method is statistically sound and allows one to use short panel series (Taylor 1984). In addition, the method can be easily extended to incorporate higher moments.[2]

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[2] Day (1965) used experimental data generated over time with the method of moments to estimate yield risk. In this study Day found that probability density functions which involved the third and fourth moments of production better described the production process. He concluded that ideally, risk measures should be based on higher order information about

3.3 Estimation of Risk Attitudes

There are basically two methods of empirical estimation of risk attitudes that are identified in the literature. Following Newberry and Stiglitz (1981), these will be called the direct and indirect approaches and are defined below. This section will proceed first by briefly outlining the theory behind risk attitude estimation.

3.3.1 The Theoretical Representation of Risk Attitudes

Risk attitude estimation is based on the shape of the utility function and on the expected payoff of a given gamble. For instance, given any two levels of income denoted x and y with equal probability of occuring p, the expected value of the gamble may be defined as $M = px+(1-p)y$. Also, given a utility function u the expected utility from this gamble may be defined as $pu(x)+(1-p)u(y)$. If the consumer whose preferences are represented by this utility function prefers the utility from the certain income M to the gamble then this consumer exhibits risk averse behaviour. In this case a chord drawn between any two points on the utility function is below the utility function (top diagram of Figure 3.1). This defines concavity of the utility function. On the other hand, if the consumer is indifferent between utility from the certain income M and the gamble then the individual is risk neutral. Similarly, if the consumer prefers the gamble to utility from the certain outcome (M) then the consumer exhibits risk loving behaviour. In this case a chord drawn between any two points on the utility function is above the utility function (bottom diagram of Figure 3.1). A utility function exhibiting this property is

the probability density function than is contained in estimates of the variance alone.

defined as convex. Therefore, the more concave a utility function the more risk averse the individual whose preferences are described by the particular utility function (Varian 1984; Robison and Barry 1987).

The second derivative of the utility function can therefore be taken as a measure of the degree of risk aversion. However, this measure is not invariant to changes in the expected utility function. This was the motivation for the absolute and relative measures of risk aversion developed by Arrow and Pratt. The Arrow-Pratt absolute measure of risk aversion is $r_A(y) = -u''(y)/u'(y)$ and the relative measure is $r_R(y) = y\{-u''(y)/u'(y)\}$, where y is the level of wealth, and u'', u' are respectively the second and first derivatives of the utility function with respect to wealth. Unlike the absolute measure of risk aversion, the relative measure is also invariant to the level of wealth at which it is estimated. An alternative measure of risk aversion is the partial relative risk aversion parameter $r_P(y,d) = -d\{u''(y+d)/u'(y+d)\}$, where d is a measure of dispersion of the distribution of wealth. This measure has the advantage over the Arrow-Pratt measure of allowing the risk associated with a given level of wealth to change while the level of wealth remains constant (Zeckhauser and Keeler 1970; Fleisher and Robison 1985).

Another measure of risk aversion is the risk premium assoicated with a gamble. The certainty equivalent associated with a given gamble is defined as that level of income that yields the same level of utility as the gamble. The cost of risk or the risk premium arises therefore, as the difference between the expected payoff of the gamble (M) and the certainty equivalent income (Robison and Berry 1987:4)[3].

Finally, Karni (1979) defines a measure of risk aversion that depends on an indirect utility function which has more than one random variable as its arguement. Karni defines a von Neuman-Morgenstern utility function u(y,c) where c is a vector of attributes that affect utility from a given income level and are also subject to uncertainty. Examples of the elements that might make up c are: prices of goods, health, future income streams, any externalities, and non-price attributes such as the time endowment of the household. This utility function is 'state contingent' in the sense that the level of utility depends on the level of the other attributes of utility. The risk aversion parameter is then defined as the matrix $R = \left[-\frac{u_{ij}}{u_y}\right]$ with elements r_{ij} . This is a more realistic measure of risk aversion since it explicitly incorporates the effects of price and income risk. Finkelshtain points out that this measure of risk aversion is particularly relevant for the agricultural household. For the agricultural household that also consumes part of what it produces, one would expect to have a measure of risk aversion which is based on an indirect utility function which has prices as well as income as arguments. The explanation for this follows from the usual measure of risk aversion which is derived from the indirect utility function assuming prices are constant. If consumption and production decisions are not interdependent one can make this simplifying assumption

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3 See also Finkelshtain (1990:15) for a definition of the risk premium within the context of multivariate risk.

without any strong biases. This could be the case in developed economies where risk markets are sufficiently developed. However, in the case of agricultural households within a developing country context, it is a better approximation of reality to use a measure of risk aversion which also allows prices to vary.

In the case of multi-variate risk, concavity of the utility function is not enough to ensure that the risk premium is positive for this measure of risk aversion. In addition, to concavity of the utility function one of two other conditions must hold in order to ensure a positive risk premium: either the marginal utility of income must be constant as the elements in the vector c change; or the risky elements in c must be independent of income (Finkelshtain 1990:18-20).

Sandmo (1971) showed that for the competitive firm, concavity of the utility function is enough to ensure a positive risk premium. As a result, output under price uncertainty will be less than under certainty. However, Finkelshtain and Chalfant (1991) show that this may not necessarily be the case for the semi-subsistent household which experiences multi-variate risk. As stated above, with multi-variate risk, the sign of the risk premium is ambiguous. Therefore, the level of output under price uncertainty may be less, equal, or more than the level of output under certainty for the semi-subsistent household.[4]

The above measures are based on the shape of the utility function. There are studies which argue that risk aversion may be induced through market imperfections.

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[4] This is intuitively appealing for the agricultural household because under certain conditions (discussed in Finkelshtain and Chalfant) and that will be elaborated on later the household may produce more under uncertainty than certainty.

Masson (1972) and Roumasset (1979) state that risk aversion may arise not only as a result of the shape of the utility function but also as a result of market imperfections. Just (1975) gives an example of this where market distortion arises from risk in the presence of underdeveloped insurance markets. Unlike the Sandmo case, risk neutrality is not enough to ensure that price is equated with marginal cost. These studies imply that all deviations of price from marginal cost is a consequence of risk. Other binding constraints that may give rise to this same result are not considered.

The existence of risk is a cost in that it distorts market cost curves and therefore affects welfare. The above papers appear to equate the shadow cost of risk with risk preferences as derived from the shape of the utility function. Thus, there is a need to distinguish between risk aversion arising from inherent preferences in the utility function and firm behaviour which is a reflection of market imperfections. In the empirical estimation of risk attitudes, marketing and transaction costs should be viewed as either fixed costs or variable costs and thus should not bias risk attitude estimation. The problem in this instance arises because of market imperfections or binding constraints[5] that give rise to additional costs not accounted for in observed prices which affect welfare.

Moscardi and de Janvry (1977) try to handle this problem by screening data for any binding constraints so that only those inputs which are traded freely in the market are used in risk attitude estimation. Alternatively Antle suggests that the objective to be optimized by the household should be correctly specified to include any binding

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[5] These binding constraints may include: imperfect credit and labour markets, and liquidity constraints (see Mason 1972).

constraints. As a result, estimated risk attitude parameters should be actual measures of the pure risk effect as opposed to measures which include both the risk effect and the effect of other market imperfections (Antle 1987 and 1989).

3.3.2 The Empirical Representation of Risk Attitudes

In the literature, measures of risk aversion have been based on the Arrow-Pratt measures of absolute and relative risk averison and on Zeckhauser and Keeler's measure of partial relative risk aversion. There are two basic approaches in the literature to the estimation of these risk attitudes. These approaches will be identified respectively as the direct and indirect approaches to producer risk attitude estimation. The direct approach involves the direct elicitation of the producers' utility function through interviews conducted with producers to determine their preferences (Dillon and Scandizzo 1978) or through experiments designed to determine the same preferences (Binswanger 1980).

The indirect approach on the other hand involves using observed data on producers' allocation decisions and resource endowments to determine their attitudes toward risk. This approach includes the programming approach (Weins 1976; Roumasset 1976; Low 1974) and the econometric approach (Moscardi and de Janvry 1977; Shahabuddin et.al. 1984; Antle 1989, 1984). Studies that use the indirect and direct approaches to elicit the risk attitudes of subsistence farmers will be summarized below in order to give some idea of the issues involved in empirical estimation and possible magnitude of the estimates.

3.3.3 Risk Attitudes of Subsistence Farmers

The Direct Approach

Dillon and Scandizzo (1978) test the hypothesis that farmers have different attitudes toward risk when subsistence is assured than when not assured and that share croppers and land owners have different attitudes toward risk. Farmers in northeastern Brazil were interviewed by asking them questions that would elicit their certainty equivalent level of income. Questions were asked with subsistence at risk and with subsistence not at risk. The gambles were framed within the context of the likelihood of yield and income in a given number of years out of four with subsistence at risk and subsistence not at risk. The authors derived risk attitude coefficients from three different specifications of the utility function which they define as: mean-standard deviation, mean-variance, and exponential[6]. They found that for both group of farmers across all utility specifications they were more risk averse when subsistence was at risk. However, the question of whether share croppers were more risk averse than landowners depended on which specification of the utility function was used. This result was to be expected since

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[6] The functional form for these are specified respectively as:

$$U=E+\alpha V^{1/2}$$
$$U=E+\beta(E^2+V)$$
$$U=\int_{-\infty}^{\infty}(1-e^{\gamma X})(1-e^{\gamma})^{-1}f(X)\,dX$$

where, U is the level of utility,
E is the mean level of income,
V is the variance in income,
X is a risky prospect (i.e. income) with,
f(X) the proability distribution function,
α, β, and γ are the risk attitude coefficients for each respective specification of the utility function (Dillon and Scandizzo 1978).

measures of risk aversion may vary according to the utility function and also according to the risk characteristics of a given utility function--the change in the risk parameter as wealth changes.

Binswanger (1980) replicated the Dillon and Scandizzo interview approach but found that the repsonses were subject to interviewer bias. Therefore, Binswanger developed an alternate experiment which was designed to elicit risk attitudes as measured by partial relative risk aversion. The farmers' concern with subsistence was not explicitly modelled. The experiment was designed to elicit the partial risk attitudes of 330 Indian villagers using gambles with real payoffs. It was assumed that the villagers made decisions according to the expected utility hypothesis, that they would exhibit constant partial risk aversion, and that the preference ranking of alternative real gambles would accurately reflect a farmer's actual preferences. First, reliability tests were conducted to see whether an individual's behaviour differed when gift money as opposed to own money was used in the gamble. Also, it was found that after individuals became familiar with the game they could accurately predict in a hypothetical situation how they would react to an actual gamble (at half, 5, 50 rupee levels). The results were that at low levels of income, partial risk aversion coefficients were fairly evenly distributed from risk neutrality to risk aversion. As payoff levels increased the degree of risk aversion increased. For individuals with initially low levels of risk aversion their risk aversion parameters increased rapidly whereas, those with moderate levels of risk aversion experienced a slow increase in their parameters or none at all.

Binswanger found a similar range of estimates and dispersion of the risk attitude parameters as Dillon and Scandizzo (with their measure of risk attitudes which was based on the risk premium) in the interview approach. It was found that the interview approach classified more individuals as severely risk averse and risk loving, whereas the experimental approach classified more individuals as moderately risk averse. Therefore, there appeared to be more dispersion in risk attitudes with the interview approach than with the experimental approach. This result may arise out of the fact that in the experimental approach, subsistence was not at risk. One would expect the distribution of risk attitude parameters to be more dispersed with subsistence at risk. This would reflect differences between households that exhibit 'desperate' behaviour because they are not meeting their consumption requirements and households which are able to meet most of their consumption requirements. Households exhibiting 'desperate' behaviour may be more willing to take gambles to improve their welfare. Whereas, households which are meeting their consumption requirements but exhibit risk averse behaviour would be more cautious in taking risks in order to maintain their level of food security. In addition, Binswanger points out that the interview approach was based on a stream of income whereas the experimental approach was based on one-period gambles. Therefore the two methods may be measuring different concepts of partial risk aversion.

The Indirect Approach

The indirect methods of eliciting risk attitudes of agricultural households in the literature relies either on mathematical programming or econometric techniques. In the mathematical programming literature most models have assumed that capital markets are well developed and therefore, that separability between consumption and production decisions exist. One example of this is a study by Brink and McCarl (1978). Programming models that have attempted to recognize the possible interdependence between production and consumption decisions among agricultural households include Low (1974) and Wiens (1976). These studies are based on the safety-first criteria developed by Roy (1952).

Wiens (1976) assumes a quadratic utility function with normally distributed profits. This study uses a programming approach to estimate risk aversion parameters using data from 21 farms in North China for the years 1937-1939. Wiens demonstrates that peasants exhibit substantial risk aversion which tends to decrease with farm size. The study concludes that in this region of China, the farmers' level of risk aversion more adequately explains the pattern of crops grown and factor employment observed than risk neutral preferences with liquidity constraints. Risk aversion parameters for small farms was estimated at .091 and for large farms at .0085. Wiens found that the farms exhibited decreasing absolute risk aversion with increased wealth. However, these studies do not attempt to model the agricultural household's decision process in determining its level of subsistence. In addition, it is difficult to use these models to develop a model that can examine the distribution of the risk parameter across a population of households (Newberry and Stiglitz 1981: 108). Shahabuddin et.al. (1984) and Moscardi and de Janvry (1977) try to address these problems.

Shahabuddin et.al. (1984) incorporated Roy's safety-first measure into a model of resource allocation. An econometric model based on the first order conditions of expected profit maximization was used to compute risk coefficients. This model takes into account the distrbution of profit and the disaster level of income. The disaster level of income was defined as the level of income that the household is capable of earning (net of minimum consumption requirements) given complete crop failure or zero income from agricultural activities. The disaster income may be interpreted as reflecting how well a family is able to smooth consumption requirements using income from other sources. It may also be interpreted as a payoff to a household if it looses the gamble of agricultural production. Therefore, if the estimated value of the risk coefficient is low and negative, the household is able to smooth consumption from other sources. If it is high, then consumption requirements outweigh the household's ability to generate income from other sources. Estimated risk coefficients for his sample of households (in four villages in Bangladesh) ranged between -1.86 to 2.73 for rural households in Bangladesh. Within this framework, choices by farmers depend on their subsistence needs, resource endowments and perceptions of the riskiness among competing activities and not on attitudes towards risk in the sense defined above. Therefore, with a positive risk coefficient this implies that in the attempt to minimize the probability of disaster, the farm household is forced to gamble in its choice of crop-portfolio. It takes risks in order to maximize its chance of survival by devoting greater resources to riskier but more profitable (higher expected profit) crops. Whereas, if the farm family's subsistence needs are lower than expected income (negative risk coefficient) then the farm family can afford to choose a less risky crop-portfolio with lower expected returns. The measure of risk aversion derived by the authors is not strictly a measure of the concavity of the utility function. This measure also incorporates the household's ability to smooth its consumption in the event of disaster (Shahabuddin et.al. 1984:2). However, this parameter cannot be compared to the risk parameters derived from the shape of the expected utility function.

The study by Moscardi and de Janvry (1977) is also based on the safety first criterion. Their hypothesis is that given a production technology, source of risk (such as variability in prices and yields), and market conditions, the observed level of factor use reveals the underlying degree of risk aversion. Therefore, it is possible to estimate risk aversion parameters for large samples of peasants (Moscardi and de Janvry). The risk attitude of forty-five farmers in Puebla, Mexico was estimated. Optimal levels of nitrogen was used in the risk attitude estimation. Nitrogen was used because it was found to be the most important input, it comprised the largest component of variable costs. The study found farmers to be risk averse with parameter estimates ranging from 0-2 with a mean of 1.12, and variance of .38.

Moscardi and de Janvry use an econometric approach to estimate the risk coefficient for a population of producers. They obtain the certainty equivalent of the safety first model subject to the constraint that the marginal rate of substitution between expected returns and variance in returns is a function of socioeconomic variables. As with Shahabuddin et.al. the risk aversion parameter is estimated from the residual of the first order condition. A criticism of this approach is that it attributes deviations from optimal allocation of factors of production to risk.

Antle's methodology for risk attitude estimation is based on the expected utility hypothesis and the statistical methodology of the method of moments (Mood, Graybill and Boes 1974). A Generalized Least Squares (GLS) estimator is used to estimate the moments of production. Antle first estimates the first moment of production (the mean) as a function of the inputs to production. He then uses the residuals from this regression to estimate the second and third moments of production (varaince and skewness respectively) as a function of the inputs to production. Afterwards, the results from the estimation of these moments of production are used as variables, and the functional form from the first order condition of optimatization of production with respect to the level of inputs are used to estimate the risk attitude of the household. In order to account for the possible endogeneity of risk attitudes, a random coefficient model with an instrumental variable estimator is used to derive risk attitudes for agricultural households in India. As mentioned earlier in this review, a criticsm of this approach is that it is important to correctly specify the mean function of production in order to derive unbiased estimates of the other moments of production. However, for the purposes of the current study the assumption made by Antle was maintained. It was assumed that the functional form represented a Taylor series expansion of inputs about the level of output. This specifications allows for a flexible and linear representation of the moment functions (see Section 3.2.2 of this review and Antle 1983:195).

The study by Antle (as do the previously mentioned econometric studies) focuses on the characteristics of a population of producers rather than on an individual producer. As a result, the problem of aggregation of individual producer attitudes toward risk to the population is eliminated. This is important for policy purposes because policy is often based on population characteristics rather than on a representative producer. Antle estimates an average absolute Arrow-Pratt risk aversion parameter value of 3.272 which he transforms to partial risk aversion measures with the range over all producers of .19 to 1.77 and he finds these to be of the same order as that estimated by Binswanger of partial Arrow-Pratt coefficients in the interval of .32 to 1.74.

The programming and econometric studies reviewed above do not explicitly model the semi-subsistent nature of the agricultural household (Finkelshtain and Chalfant 1991). In addition, these models do not take into account that these households may be able to smooth consumption through other sources such as off-farm income and savings. Murdoch states that neglecting this may lead to lower estimates of risk aversion parameters and an over-estimation of the effect of risk on consumption.

Morduch (1990) used the same data set as Antle (1989) within the agricultural household model framework to estimate risk preferences. He assumes a sequential decision process where production decisions are made first based on risks faced by households. Afterwards, consumption decisions are made given the outcome of production decisions. He argues that if the household is able to smooth consumption through credit, off-farm income, gifts etc., then the effect of risk on consumption is less than it would be if these alternatives were not available. Therefore, it would appear that past studies of risk attitude estimation (using the observed behaviour approach) which did not account for the consumption preferences of the household may lead to an overstating of the effect of risk on consumption and an understating of risk attitudes.

This hypothesis is supported by a comparison of the coefficients of relative risk aversion estimated by Morduch to those estimated by Antle (1989). The estimates of relative risk aversion estimated by Morduch are slightly higher than those estimated by Antle (1989) using the same data. In light of this result, one can see how the Dillon and Scandizzo (1978) results (which allow subsistence to be at risk) may reflect more closely the actual situation of poorer farmers than the Binswanger approach. Also, the above hypothesis provides another explanation for the differences between the results obtained by Dillon and Scandizzo and Binswanger.

Fafchamps (1990:192) uses monthly data on Burkina Faso between the years of 1981 - 1983 to estimate relative risk aversion parameters within the range of 0 to .99. These estimates of partial relative risk aversion appear to be rather low. In this study Fafchamps explicitly models the endogeneous return to household labour. One would expect that including missing markets in the model would increase the impact of income risk on consumption since the ability to smooth consumption through the labour market is limited. Also, one would expect the risk aversion parameters to be higher because of the interdependence of consumption and production decisions.

The results from the above studies lead to the conclusion that agricultural households are primarily risk averse. The measure of absolute risk aversion varies across studies and appears to be lower for the math programming than the econometric studies. Murdoch states that these approaches do not take into account the household's ability to smooth its consumption inter-temporally or from other income sources. As a result, econometric estimation of risk attitudes (which is based on actual or observed behaviour) may under state the estimate of risk aversion. Since, households which have various sources of smoothing its consumption available to it (off-farm income, credit, gifts etc.) may behave as if they are risk neutral. In fact, such a household may be less concerned with the variation in income if it knows that it will be able to meet its consumption requirements and will therefore be more willing to trade off the cost of higher risk with higher expected returns.

The next section will examine how the risk parameter varies across a population of semi-subsistent households. This has implications for income distribution, risk bearing or consumption smoothing ability and therefore food security policy.

3.3.4 The Relationship between Risk Attitudes and Socioeconomic variables: Policy Implications

Dillon and Scandizzo (1978) found that an increase in the risk aversion coefficient was correlated with ethical beliefs about gambling and age. Increases in risk aversion was found to be correlated with increases in household size for home owners. Moscardi and de Janvry (1977) used discriminant analysis with three variables representing the socio-economic aspects of the household: nature of the household represented by family size, age and education of household head; income generating opportunities represented by land under its control, level of off-farm income; access to public institutions represented by membership in a solidarity group (cooperative).

The results were that increases in the risk aversion parameter was positively correlated with age and negatively correlated with education, household size, off-farm income, land control, and solidarity group. This suggests decreasing risk aversion as wealth increases.

Binswanger (1982) regressed eleven socio-economic and structural characteristics on partial risk aversion coefficients derived for peasants in rural India. The study found that wealth had a negatively insignificant effect on the risk aversion coefficient and had a weak negative correlation with education. Past experience with playing gambles or luck was highly correlated with the risk aversion coefficient. Success in prior games was found to be negatively correlated with increased risk aversion. However, the effect of luck decreased as the stakes rose. Increasing risk aversion was positively correlated with age at the half rupee and five rupee levels but negatively correlated with age at higher game levels. As with Dillon and Scandizzo tenants were shown to be less risk averse than landlords at low game levels. There was a negative correlation between risk aversion and income transfers. Binswanger concludes that the difference in investment behaviour observed among farmers facing similar technologies and risks cannot be explained prmarily by inherent risk attitudes, but instead are induced by the existence of differing constraint sets. This implies that consumption smoothing or risk bearing ability would determine the degree to which risk affects consumption and production decisions for agricultural households in the presence of under-developed credit markets.

Shahabuddin et.al. (1984) regressed their measure of risk coefficients on socio-economic variables (age of head of household, family size, education level, farm size, off-farm income, total assets of household). He found that the household's asset and education position was never significant in determining risk behaviour. Family size was found to be positively correlated with the risk coefficient and farm size and off-farm income were found to be negatively correlated with the risk coefficient.

The above discussion shows that the existence of risk may adversely affect the distribution of income among agricultural households in developing countries. This would have adverse consequences for food security in these areas. It is therefore important to examine the effect of risk on food consumption in order to identify policy options to aid in alleviating food insecurity. The next section will discuss previous studies that have attempted to examine this affect and the corresponding estimation issues.

3.4 Incorporating Risk into an Agricultural Household Model

3.4.1 Basic Result of the Model without Risk

The agricultural household model (AHM) was first conceptualized by Chayanov to explain the production behaviour of peasants in Russia. In this model the labour market was absent. This model was later formalized by Nakajima (1986). Since then several empirical applications of this model have been implemented (see Singh, Squire and Strauss 1986). The basic results of the model show that in the presence of perfect capital and factor markets the production side of the household's behaviour could be modelled independently of the consumption side. In other words, given prices, one could solve first for the production problem of the household. Given this result, the consumption problem of the household could then be solved. This is the recursive property of the model (separability or sequential decision making process which will be illustrated algebraically in the model chapter). The comparative static results of the model yield the result that the change in the consumption of a good (which is also produced by the household) with respect to price is no longer unambiguously negative for a normal good as in the usual consumer case. This is because the income effect has two components: a profit effect in addition to the usual income or expenditure effect. If the profit effect is zero then the comparative static result reduces to the traditional consumer case. However, if the profit effect outweighs the consumption effect (which implies a net seller household) the household may demand more of the good which it produces when its price increases. In this case, an increase in price induces the household to produce more which leads to a positive marginal increase in income and, therefore, an increase in demand if the income effect outweighs the substitution effect. Appendix 3.1 summarizes these results.

3.4.2 The Basic Result with Missing Markets

The next basic extension of the AHM is to the case of missing markets for some of the goods produced by the household: labour, health etc. In these cases, separability between consumption and production decisions no longer holds. One common example is the case of missing labour markets. The wage rate is, therefore, endogenously determined by the household and depends on production as well as consumption decisions. Examples of these kinds of models are those by: Benjamin (1992), Fafchamps (1989), and models in Singh, Squire and Strauss (1986).

Separability may also breakdown when there is risk in the presence of underdeveloped capital markets. Studies that have attempted to look at risk in the AHMs are those by: Graham-Tomasi and Roe (1986), Fabella (1989), Finkelshtain (1990), Finkelshtain and Chalfant (1991). These studies show that under general conditions separability between production and consumption decisions breaks down in the presence of risk.

3.4.3 The Basic Results and Risk

Fabella incorporates risk into a static model of the AHM and discusses different representations of production risk that would lead to separability. The paper shows that risk neutral attitudes on the part of the household implies separability. If revenue risk is multiplicative then risk neutral attitudes implies separability between consumption and production decisions. Additive production risk specification implies separability. Risk reducing inputs (in the sense of Pope and Kramer 1979) with increasing returns to scale of production leads to separability if production risk is multiplicative. The study does not examine the implications of the existence of risk for the comparative statics of the consumption of the good produced by the household. However, it provides a framework for examining the effect of risk on production decisions in a static framework which will be developed further in the current study.

Graham-Tomasi and Roe (1986) use a dynamic model of AHM with multiplicative risk and assume normally distributed production risk to show that separability holds under the following conditions: the utility function is additively separable over time with each period's sub-utility function being negative exponential. The exponents of the utility function is restricted to be homothetic with respect to the consumption bundles. In this special case, the household behaves as if it first maximizes certainty equivalent income with respect to inputs and outputs. Given this certainty equivalent income it optimizes its utility. The result is that the profit effect is no longer unambiguously positive (as in the basic AHM). For the net seller, if the increase in the variance of profit (as a result of a price increase in the presence of risk) outweighs the increase in the expected profit then the net income effect is negative. Assuming the household is risk averse, an increase in the price of the good produced by the household leads to a larger decline (or a smaller increase if the net income effect is positive) in its demand than if there was no risk. In the case of the net buyer, this household experiences an unambiguously greater decline in demand with the existence of risk. The major criticism of this model is that it does not take into account the household's ability to smooth its consumption and the effect of increased risk on consumption. Therefore, this model may tend to overstate the effect of risk on consumption. Few studies have explicitly accounted for the household's ability to smooth its consumption in the presence of risk and the net impact on consumption. However, studies such as Murdoch (1990) which examine the effect of credit constraints on production decisions may highlight the importance of accounting for consumption smoothing and alternate income sources.

Murdoch (1990) incorporates saving and borrowing into the AHM using a dynamic model to look at the effect of borrowing constraints on production decisions. He assumes a sequential decision process where consumption decisions are made after production has been realized. He finds that households which are constrained diversify plots and crops and adopt less risky technologies to a greater extent than unconstrained households. He also found that households with smaller plots of land were more credit constrained than families with larger plots of land. This model does not examine the effect of increased risk on consumption. However, it does emphasize the importance of incorporating risk into an analysis of economic decision making within an agricultural household. The model also highlights the importance of the availability of alternate income sources and means of smoothing consumption to the household.

Finkelshtain (1990) uses the AHM framework to show that under multivariate risk without imposing a sequential decision making process, the semi-subsistent household may produce more under price risk than it would under deterministic prices. He derives the result that the agricultural household will produce less (more) in the presence of risky prices if the income effect of a price increase outweighs (is outweighed by) the consumption effect. The implication for the price response of the Marshallian demand curve is that buyer and seller households will unambiguously be worse off in the presence of risk. However, seller households may still experience an increase in demand depending on whether the net income effect outweighs the pure substitution effect.

The above review shows that few studies have attempted to trace in a theoretically consistent manner the linkage between production risks and consumption decisions and therefore food security of semi-subsistent households. The different studies touch on various aspects of the issue without explicitly outlining the link between the risks and household food security.

From the current attempts to incorporate risk into an AHM one can see that changes in the basic comparative static results of the model are brought about through the net income effect. Therefore, in an attempt to explore the effect of risk on consumption it will be important to derive a method to isolate the profit and expenditure components of the net income effect. However, techniques are still lacking which examine the way in which these risks translate into food insecurity. The degree to which these risks translate into food insecurity depends on the households' ability to smooth consumption. There exists a growing body of literature on risk and its effect on household consumption in developing areas. Alderman and Paxson provide a review of these studies which are primarily based on the permanent income literature. In these studies consumption is correlated with income to see the degree to which the two move together. If the two are perfectly correlated then this implies that there is a significant degree of liquidity constraints. However, very few of these studies explicitly account for the semi-subsistent nature of the agricultural household.

3.5 Implications for Empirical Estimation

Given the above discussion it will be necessary to estimate demand responses in the presence of risk. Some issues need to be explored with regard to estimation of the demand system. In cross-section data there are often zero observations for some of the goods which are either not consumed by a household, or not bought by the household in the period in which the survey was conducted. This is known as censoring of the dependent variable, which violates the assumption of normality and a zero expected value of the ordinary least square (OLS) error term.

Censoring may be handled in different ways. One approach may be to aggregate across commodity groups. However, some information may be lost in the process. Another approach would be to drop the zero observations. However, this would lead to biased OLS results because the estimates would not reflect the behaviour of the whole sample (Alderman 1986).

Tobit models are used to account for this censoring in the dependent variable (Pudney 1989; Maddala 1983). The basic structure of the Tobit model which applies to the data for the current study may be written as follows:

$$
\begin{aligned}
Y^{*} &= \beta' X + \epsilon \\
Y &= 0 \quad \textit{if } Y^{*} \leq 0 \\
Y &> 0 \quad \textit{if } Y^{*} > 0
\end{aligned}
$$

where, Y^* is the unobservable latent variable

Y is the observed censored variable (which for the current case is the expenditure share of each food group out of total food expenditure and is censored at zero)

β is the estimated coefficients

ϵ is the independent error term which is normally distributed about 0 with a variance of σ^2.

This model was first proposed by Tobin (1958) who applied this model to consumption of durables and showed that (by using the moments of censored normal variable (see Greene)) that :

$$EY = \beta' X \Phi(z) + \sigma \phi(z)$$
$$\text{where } z = \frac{\beta' X}{\sigma},$$

$\Phi(z)$ is the cumulative distribution function and $\phi(z)$ is the density function.

McDonald and Moffitt (1980) decompose the marginal effect for censored variable into two components: the probability of being censored times the change in the expected censored value plus the expected censored value times the change in the probability of being censored. In other words, an exogeneous change effects the censored variable in two ways: the mean effect on the censored value and the probability of it being censored. This marginal effect is important for those cases in which the distribution is truncated. In this case one is interested in the marginal effects of the exogeneous variables on the censored observed variable. However, if one is interested in the underlying distribution (and not just in the observed values) then the estimated coefficients β measure this effect. In the current study we will be interested in the underlying distribution.

There is also an interpretation for the latent variable within the context of the present study. Food items will be grouped into six food groups. It is assumed that members in a household will consume at least one item out of each of these groups in a long enough time period. The survey period may have been too short to catch consumption of these items. Also, quite a few of the food items are storable which may contribute to non-expenditure outside of the survey period. In this case, the observed variable Y represents expenditure on food in a time period. Whereas, the latent variable Y^* represents actual consumption out of food expenditure in a time period.

A two step-procedure has been proposed by Amemiya (1978) and Heckman (1978) in estimating the above equation. The method to be used in the current study will be that of Lee (1978) which has been applied to an AIDS demand system for food by Heien and Wessells (1990). This method was chosen because it readily lends itself to the maintained hypotheses of demand theory: adding up and symmetry.

A second issue in demand system estimation in cross-sections involves the use of unit values in estimating price changes. Usually, in cross-sectional surveys, quantity and expenditure information is collected but not spatial price data. Unit values therefore represent quality as well as quantity variations in addition to measurement error. Therefore, using unit values to estimate price response of demand will bias the results of the price elasticties. Deaton (1988) provides a methodology that isolates the quality effects of price changes and that also accounts for measurement error. Alternatively, one could use average market prices across districts and this reduces the level of measurement error and quality effects (Strauss 1986). This is the method employed in the present study.

Finally, there is the issue of whether to incorporate the production side of the household decision process and how to do so. In order to determine whether the production side should be incorporated in some fashion the usual procedure is to perform a Hausman test for the exogeneity of expenditure or income in the demand equation (Bouis and Haddad 1990). Also, indications of the non-existence or inefficient functioning of markets in the area to be studied lead to the implication that production decisions should be incorporated into consumption decisions. Two stage least squares with instrumental variables may be used to account for the possible endogeneity of income or expenditure in consumption decisions. Also, using instrumental variable estimation minimizes the possible effects of measurement error. In addition to the above, Massell (1969) suggests including the degree of subsistent orientation out of production as an independent variable. He argues that for semi-subsistent households it is likely that the household which grows more of a given good will consume more of that good. This is because the imputed cost of the good is lower to the household which grows it as compared to purchasing it on the market. Incorporating subsistence orientation accounts for the possible effects of transaction costs on consumption. Massell therefore concludes that excluding this variable will lead to biased results for households that consume a significant amount of what they produce. This variable is also instrumented as in the expenditure or income case.

3.6 Conclusion

From the review of the above articles it appears that semi-subsistent households are generally risk averse. The risk affects food security through its effect directly on food consumption and indirectly on resource allocation decisions. The degree to which this occurs depends on the households ability to smooth consumption and diversify income risks. However, there is still a need for studies that link in a theorectically consistent manner the risks faced by semi-subsistent households and food insecurity.

The current study will attempt to develop a framework within which the effect of risk on agricultural household food consumption may be examined. The study will be primarily concerned with labour supply as the means of smoothing consumption. In the Rwandan case, labour is important because of the implications for employment in population dense areas and also because of the implications for the nutritional status of children through its effect on women's time allocation.

Appendix 3.1: Summary of the Comparative Static Result

The Usual Comparative Static Result of Demand Theory

$$\frac{\partial S}{\partial P}\Big|_M = \frac{\partial S}{\partial P}\Big|_H - S\frac{\partial S}{\partial Y}$$
$$\epsilon = E - s_M\eta$$

where, S is the amount of the good consumed by the household

P is the price of S

Y is income or total expenditure, and

M is the Marshallian response of demand to a price change (Y constant)

H is the Hicksian reponse of demand to a price change (utility constant).

ϵ is the Marshallian price elasticity of demand,

η is the income elasticity of demand,

E is the Hicksian elasticity of demand,

s_M is the share of the good consumed out of total expenditures.

The Comparative Static Result of Demand Theory in the AHM

$$\frac{\partial S}{\partial P}\Big|_M = \frac{\partial S}{\partial P}\Big|_H + \left(\frac{\partial \pi}{\partial P}\frac{\partial S}{\partial Y} - \frac{\partial Y}{\partial P}\frac{\partial S}{\partial Y}\right)$$
$$= \frac{\partial S}{\partial P}\Big|_H + (Q - S)\frac{\partial S}{\partial Y}$$
$$\epsilon = E + (\beta - s_M)\eta$$

where, S is the amount of the good consumed which is produced by the household

Q is the amount of the good produced,

β is the share of the good produced out of total income, all other variables are as defined above.

Appendix 3.2: Summary of the Comparative Static Result of Demand in the AHM with Risk

The Graham-Tomasi and Roe Model (Production Risk)

$$\frac{\partial S}{\partial P}\Big|_M = \frac{\partial S}{\partial P}\Big|_H + \left(\frac{\partial \Pi_{CE}}{\partial P}\frac{\partial S}{\partial Y} - \frac{\partial Y}{\partial P}\frac{\partial S}{\partial Y}\right)$$

$$= \frac{\partial S}{\partial P}\Big|_H + (Q - P\,V(Q)\;r - S)\frac{\partial S}{\partial Y}$$

$$\epsilon = E + (\beta - s_M)\eta - \frac{V(\Pi)\,r}{Y}$$

where, Π_{CE} = P*Q(k,l) - C(k,l) - P^2*V(Q)*r/2 = Π - P^2*V(Q)*r/2, is certainty equivalent income,

Y = Π_{CE} + P^2*V(Q)*r/2 + I, is expected income with I exogeneous income,

Q is the expected level of risky output with variance V(Q), r is measure of relative risk aversion, and all other variables are as defined in Appendix 3.1.

The Finkelshtain and Chalfant Model (Price Risk)

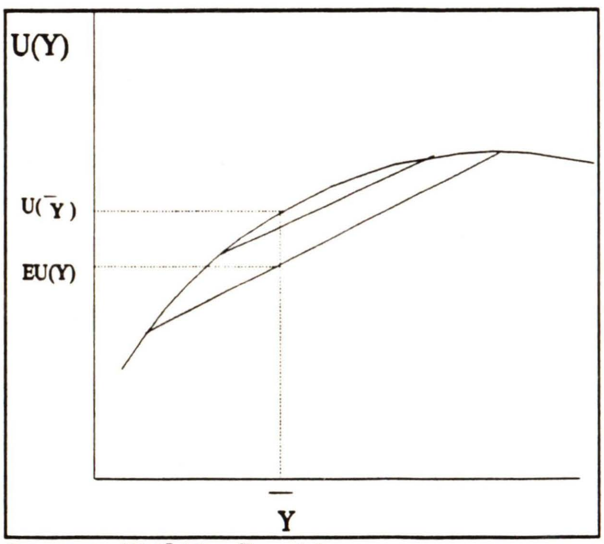
$$\frac{\partial S}{\partial P}\bigg|_M = \frac{\partial S}{\partial P}\bigg|_F + \left(\frac{\partial \Pi}{\partial P}\frac{\partial S}{\partial Y} - \frac{\partial Y}{\partial P}\frac{\partial S}{\partial Y}\right)$$

$$\epsilon = F + (\beta - s_M)\eta$$

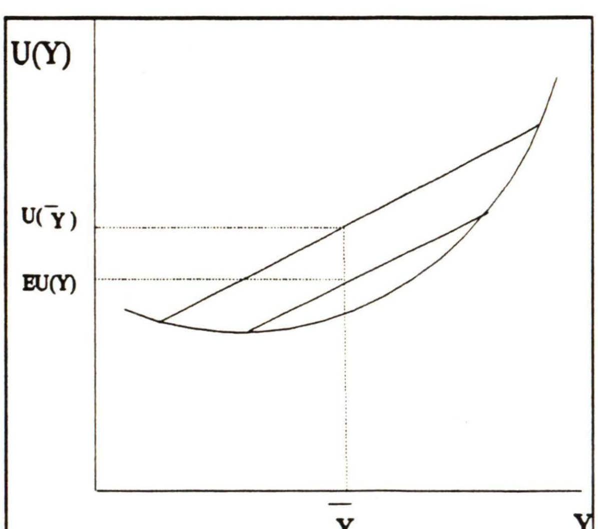
$$= E - s_M r\mu^2 + (\beta - s_M)\eta$$

where, subscript F denotes constant marginal utility of income demand curves or Frischian demand curves (see Besley (1989); Frisch (1959) and Browning et. al. (1985); Phlips (1983)). The Hicksian substitution effect may be decomposed as follows $E=F + s_M r\mu^2$. Therefore, $F = E - s_M r\mu^2$ where the first term is the pure substitution effect and the second term is the income effect or the compensation required to keep marginal utility of income constant.

Figure 3.1: The Effect of a Mean Preserving Spread on Expected Utility



Concave Utility Function



Convex Utility Function

Source: Newberry and Stiglitz 1981.

CHAPTER FOUR
RISK IN A STATIC FRAMEWORK OF THE AGRICULTURAL HOUSEHOLD: ITS EFFECT ON CONSUMPTION AND LABOUR ALLOCATION

4.1 Introduction

This chapter outlines the theoretical framework that will be used in the econometric analysis of the effect of risk on the consumption and labour supply decisions of agricultural households in Rwanda and the implications for household food security. The framework will provide the background for the econometric models to be used in a micro-simulation of the pricing policy for staple foods in Rwanda. It will take into account the possible endogeneity of family labour and allow for heterogeneity between family and hired labour and between family male and female labour. Given the subsistent nature of Rwandan households, the model will also allow for the simultaneous determination of consumption and production decisions.

Agricultural household models (Singh Squire and Strauss) allow for the possible interdependence of production and consumption decisions without the explicit consideration of risk. The incorporation of risk into the model raises two issues regarding separability and the allocation of resources. With regard to separability, Barnum and Squire state that the existence of contingent claim markets or risk neutral preferences guarantees separability under risky situations. Although, Fabella (1989) shows that additive production risk in a static model of the agricultural household gives rise to the result of separability. Roe and Graham-Tomasi (1986) find that separability between consumption and production decisions does not hold in general. In their paper, a dynamic model of the agricultural household with multiplicative production risk is developed. It was found that the income effect of a change in price of a good also produced by the household was overestimated when risk was not explicitly incorporated into the model. It was also found that the quantity of output was overestimated and the resources allocated to off-farm activities was underestimated when risk was not considered.

In the Rwandan case, the issue of separability arises because family labour may be allocated to on-farm and off-farm activities. Households simultaneously determine how much leisure to consume and how much of their own labour to allocate to on-farm activities. The high population density of the region in the current study gives rise to the possiblity that not everyone looking for work outside of the farm may be able to find it. The data for Giciye commune shows that the market wage rate exceeds the marginal product of farm labour. This suggests that there is some rationing in the labour market that is causing households to supply 'too much' labour on their farms. As a result, the wage rate for family labour will be endogeneously determined. Therefore, there may be a wedge between the market wage rate and the return to on-farm family labour. This will have policy implications for household food security. The chapter will begin by first formulating the problem for the certainty case. Then the problem for the cases of price and production risk will be formulated along with the results. The key variables and relationships which will be used in estimating the effect of risk on household consumption will be identified and analyzed.

4.2 The General Model

The general model is that of an agricultural household which consumes part of its agricultural production. The household is assumed to maximize a utility function which is a function of the consumption goods: the staple food (S, which is produced and consumed by the household), all other consumption goods (C), leisure (l_F, l_M) where the subscripts F and M refer to female and male leisure respectively, and nutritional well being (NW), subject to a budget constraint which includes net revenue from production, the value of production of nutritional well being, and any sources of off-farm income for the household ($w_F OF, w_M OM$ where w_F and w_M are female and male wage rates respectively, and OF, OM are female and male off-farm labour supply).

The production function for nutritional well being is defined by $NW[S,HW,HT;\Omega]$, where Ω are exogeneous variables which effect nutritional well being (such as distance from and cleanliness of water supply, cleanliness of the household environment, education level and genetic make-up of the heads of the household), S refers to the staple good, HW is labour allocated to the production of nutritional well being (this includes general nurturing activities and housework), and HT is the amount of health services used in producing a given level of nutritional well being. The marginal product for each input to the production of nutritional well being is assumed to increase at a decreasing rate: $NW' > 0$ and $NW'' < 0$. NW is not a choice variable for the household. However, it is determined by the value of its inputs which are choice variables for the household. Farm production of the staple good, part of which is also consumed is defined by $f[F,M,H,K;NW]$. Nutritional well being is not an input to production but rather behaves as a shift variable. Nutritional well being effects production through its effect on the marginal products for family labour: $f_{F\,NW} > 0$ and $f_{M\,NW} > 0$. The variable factors of production are total female (F) and male (M) household labour supply, and hired labour (H). The fixed factors of production are the resource endowment (K) which may include land and any fixed capital. The return to this fixed resource is r_K. It is assumed that the marginal product for all inputs increase at a decreasing rate: $f' > 0$ and $f'' < 0$.

The household's utility function is assumed to be strictly quasi-concave and twice differentiable with $U' > 0$ and $U'' < 0$ for all of its arguments. It is assumed that there are no savings and that the primary means employed by households in managing risk is through the labour market. This is a restrictive but not entirely unrealistic assumption given the low level of food storage in the study area and missing credit markets.[1]

The household's general problem under certainty may be stated as follows:

[1] This assumption was also common in the older empirical risk literature. More recent works attempt to incorporate the other means employed by households in managing risk (see Alderman and Paxson).

$$\max_{\substack{F,M,S,C,\\K,H,OF,HT,\\OM,HW}} U[l_F, l_M, S, C, NW[S,HT,HW;\Omega], HT] \text{ such that} \tag{1}$$

$$p_S S + p_C C + p_{HT} HT = +pf[F,M,H,K;NW] - wH - r_K K + w_F OF + w_M OM \qquad (i)$$

$$T_F = l_F + F + HW + OF \qquad (ii)$$

$$T_M = l_M + M + OM \qquad (iii)$$

$$K \leq \bar{K};\ OF, OM \geq 0.$$

where, p_S is the imputed price to the household of consuming the home produced good S, p is the market price at which the good can be sold by the household, p_C is the price of the non-food composite good, and p_{HT} is the price of health services consumed by the household. The constraint (1i) ensures that consumption expenditure does not exceed income. In order to simplify the framework it is assumed that only women supply labour to NW production. The constraints (1ii and 1iii) ensure that labour supply does not exceed the stock of time available within the household. T_i represents the total labour time available for a household (which may be for a year, month or day) and depends on the number of males and females within the household. Lastly, the amount of the fixed resource employed in production should not exceed the amount available. In addition, off-farm labour supply may be rationed. If this is the case, then the off-farm labour supply constraints are binding.

The above model also incorporates transaction costs. The imputed price (which may also be called the shadow value of the good consumed by the household) is related to the market price as follows: $TC = p_S - p$, where i=1..n households. Transaction costs are made up of the cost of storage, costs of transportation to and from the market, opportunity cost of time involved in carrying out transactions, and risks associated with uncertain marketing conditions (de Janvry et. al. 1992; see also Goetz 1992). If transaction costs are exhorbitant then the household becomes self-sufficient.

4.2.2 The Problem under Certainty

The corresponding Lagrangean to equation (1) can be written as follows:

$$\max_{\substack{F,M,S,C,\\K,OF,OM,\\H,HW,HT}} \quad U\{T_F-F-HW-OF,\, T_M-M-OM,\, S,\, C,\, NW[S,HT,HW;\Omega],\, HT\} + \lambda\left\{\begin{array}{c} pf\,[F,M,H,K;NW]-wH-r_K K+w_F OF+w_M OM \\ -p_S S-p_C C-p_{HT} HT \end{array}\right\}$$
$$\mu\{\bar{K}-K\}+\gamma_M OM+\gamma_F OF \tag{2}$$

where λ is the marginal utility of income, μ is the shadow value of the fixed resource K, and γ_M and γ_F are the shadow values of off-farm labour. The shadow values of off-farm labour will be greater than zero if the constraint on off-farm labour supply is binding. The first order conditions for an interior solution may be written as in equation (3).

Equations (3i) and (3ii) state that within the farm household labour is supplied up to the point where its disutility equals its marginal value product. These equations show the source of the breakdown of the separability assumption since the choice of how much leisure to consume also depends on production decisions. Equating (3i) to (3viii) and (3ii) to (3vii) yields the result that each type of household labour is supplied up to the point where its marginal value product is equal to its shadow value. In the case of female labour, its shadow wage ($w_F + \gamma_F/\lambda$) is also equal to the shadow value of labour allocated to house work ($U_{NW}NW_{HW}$). The constraints on off-farm labour supply provide the basis for testing for rationed labour. If labour is rationed then, the market wage rate will not be equal to the marginal value product of labour.

(3)

$$
\begin{array}{rll}
F: & \hat{U}_{1_F} = pf_F & (i) \\
M: & \hat{U}_{1_M} = pf_M & (ii) \\
S: & \hat{U}_S + \hat{U}_{NW}NW_S = p_S & (iii) \\
C: & \hat{U}_C = p_C & (iv) \\
K: & pf_K = r_K + \frac{\mu}{\lambda} & (v) \\
H: & pf_H = w & (vi) \\
OM: & \hat{U}_{1_M} = w_M + \frac{\gamma_M}{\lambda} & (vii) \\
OF: & \hat{U}_{1_F} = w_F + \frac{\gamma_F}{\lambda} & (viii) \\
HW: & \hat{U}_{1_F} = \hat{U}_{NW}NW_{HW} & (ix) \\
therefore & pf_F = w_F + \frac{\gamma_F}{\lambda} = \hat{U}_{NW}NW_{HW} & \\
HT: & \hat{U}_{HT} + \hat{U}_{NW}NW_{HT} = p_{HT} & (x) \\
where & \hat{U}_i = \frac{U_i}{\lambda} &
\end{array}
$$

Equation 3v and 3vi state that hired labour and fixed resources (such as land) are employed by the farm up to the point where its marginal value product is equal to its price or rental value. Equation (3iii) and (3x) state that the household's choice of S and HT depends on the respective direct effect on utility and also on the respective indirect effects through the effect on nutritional well being.

4.3 The Model Under Price Uncertainty

The task in this section is to show the effect of price and yield risk on input and output levels of production. Therefore, in order to simplify the notation, the assumption that male and female labour are heterogeneous will be relaxed, and transaction costs are assumed to be zero. These assumptions do not change the basic analysis. Assuming price uncertainty, and solving for the aggregate non-food good C[2] so that all prices are relative to p_C, the above problem may be restated as follows:

$$\max_{\substack{L,S,H,\\K,HW,OF\\HT}} EU\left\{\begin{array}{c} T-L-HW-OF, S, NW[S,HT,HW;\Omega], HT, \\ (p+\alpha\theta)f[L,H,K;NW] - wH - r_K K + wOF - p_{HT}HT \\ -(p+\alpha\theta)S \end{array}\right\} + \mu\{\bar{K}-K\} + \gamma OF \tag{4}$$

In order to derive the comparative statics of the effect of a mean preserving increase in the variance of output price the random price may be defined as $p' = p + \alpha\theta$, and $E(p') = p$, where E is the expectation operator (Sandmo, Pope and Kramer). Changes in α depict a mean-preserving change in the riskiness of the price of staple S, and θ is the deviation of price from its mean. The above problem yields the first order conditions (5). When the optimal solution to equations (6) are substituted back into the objective function in (4) this yields the indirect expected utility function $V(P,Y,\alpha)$. P depicts the vector of input and output prices and Y is full-income (which is defined in Appendix 4.1).

2
$$C = \frac{p}{p_C}f[.] - \frac{w}{p_C}H - \frac{r_K}{p_C}K + \frac{w_F}{p_C}OF + \frac{w_M}{p_C}OM - \frac{p_{HT}}{p_C}HT - \frac{p}{p_C}S$$

(5)

$$\frac{\delta EU}{\delta L} = E\{-U_1+U_C(p+\alpha\theta)f_L\}=0 \qquad (i)$$

$$\frac{\delta EU}{\delta S} = E\{U_S+U_{NW}NW_S-U_C(p+\alpha\theta))\}=0 \qquad (ii)$$

$$\frac{\delta EU}{\delta K} = E\{U_C(p+\alpha\theta)f_K-U_C r_K-\mu\}=0 \qquad (iii)$$

$$\frac{\delta EU}{\delta H} = E\{U_C(p+\alpha\theta)f_H-w\}=0 \qquad (iv)$$

$$\frac{\delta EU}{\delta HW} = E\{-U_1+U_C(U_{NW}NW_{HW})\}=0 \qquad (v)$$

$$\frac{\delta EU}{\delta OF} = E\{-U_1+U_C w+\gamma\}=0 \qquad (vi)$$

$$\frac{\delta EU}{\delta HT} = E\{U_{NW}NW_{HT}+U_{HT}-U_C p_{HT}\}=0 \qquad (vii)$$

Following Horowtiz (1970)[3] (5) may be written as:

3 Horowitz passes the expectation operator through the terms in the brackets and uses the definition for the expectation of the product of two random variables:

$$E\{XY\} = E\{X\} + E\{Y\} + COV(X,Y),$$
$$\text{and } COV(X,Y)=E\{(EX-X)(EY-Y)\}$$

where COV denotes the covariance between the two random variables.

(6)

$$L:\ pf_L - \frac{EU_l}{EU_C} = \frac{cov(U_C, pf_L)}{EU_C} \qquad (i)$$

$$S:\ \frac{EU_S}{EU_C} + \frac{EU_{NW}NW_S}{EU_C}NW_S - p = \frac{cov(U_C, p)}{EU_C} \qquad (ii)$$

$$K:\ pf_K - (r_K + \frac{\mu}{\lambda}) = \frac{cov(U_C, pf_K)}{EU_C} \qquad (iii)$$

$$H:\ pf_H - w = \frac{cov(U_C, pf_H)}{EU_C} \qquad (iv)$$

$$HW:\ \frac{EU_l}{EU_C} = U_{NW}NW_{HW} \qquad (v)$$

$$OF:\ \frac{EU_l}{EU_C} = w + \frac{\gamma}{\lambda} \qquad (vi)$$

$$HT:\ \frac{EU_{HT}}{EU_C} + EU_{NW}NW_{HT} = p_{HT} \qquad (vii)$$

In equation (6) the right hand side provides a measure of the marginal risk premium associated with the respective choice variables. This marginal risk premium is a function of the level of risk.

4.3.1 The Total Effect of Price Risk on Family Labour Allocation and Production

Equation 6i (using 6vi) may be rewritten as: (7)

$$\frac{pf_L - w}{pf_L} = \frac{cov(U_C, P)}{EU_C}.$$

Equation 7 (and 6), shows how the existence of risk alters the choice rules that would prevail in the case of certainty. Following Sandmo, Battra and Ullah, and Finkelshtain and Chalfant the total effect of risk on input use can be determined by the sign of cov(U_C,p). If cov(U_C,p) < 0 then more labour is used as compared to the risk neutral situation. If cov(U_C,p) > 0 then less labour is used as compared to the risk neutral situation. In order to determine the sign of this term, Finkelshtain and Chalfant use Roy's identity and a Taylor series expansion (Newberry and Stiglitz 1981; see Appendix 4.1) to rewrite (7) as:

$$\frac{pf_L - w}{pf_L} = \psi^2 (r\beta + s_M(\eta - r)) \tag{8}$$

where ψ is the coefficient of variation in prices, r is the coefficient of relative risk aversion, w is the market wage rate or observed wages, s_M is the proportion of home consumption of the farm produced staple out of total expenditure, β is the value of the home produced good as a proportion of full income, and η is the income elasticity of demand for the home produced staple (S). Let X^U and X^C be the levels of production under price uncertainty and certainty respectively. The uncertain level of output X^U will be greater (less) than the certain level X^C as:

$$r\beta + s_M(\eta - r) \begin{matrix} < \\ = \\ > \end{matrix} 0$$

and

$$\beta \begin{matrix} < \\ = \\ > \end{matrix} s_M\left(1 - \frac{\eta}{r}\right) .$$

The consumption effect of a price change (the derivation of which is explained in Appendix 4.2) is defined as $s_M\left(1 - \frac{\eta}{r}\right)$ which is the amount by which expenditure must change in order for the household to enjoy the same level of marginal utility as before the price change (Finkelshtain and Chalfant 1991:561; Besley 1989:846). The income effect is defined as $\frac{dy}{dp}.\frac{p}{y} = x.\frac{p}{y} = \beta$ which is the amount by which income changes when prices change. The intuition behind these results arises out of the household's primary concern with ensuring itself against consumption risk. If the income effect is greater than the consumption effect then the household is able to insure itself against adverse changes in prices through the marginal increase in income. However, if the consumption effect dominates the income effect, then in order to keep marginal utility constant, the household is forced to produce over and above what it would produce if there were no risk in order to keep its marginal utility at the same level as before the price change. If the household behaves in a way that denotes risk neutral behaviour then the consumption effect and the income effect are equal. This result shows that as long as there is risk and incomplete markets, the household may behave in a fashion which denotes risk aversion even though it is risk neutral (r=0)[4]. Finkelshtain and Chalfant show that:

$$X^U \overset{<}{\underset{>}{=}} X^C \quad as \quad \eta \overset{>}{\underset{<}{=}} r\left(1-\frac{X^U}{S}\right).$$

Therefore, the household can behave in a risk neutral manner when the above result holds with equality even though the household is not risk neutral (r is not equal to zero).

The implications of risk aversion for food availability can be ascertained from

[4] Masson (1972) and Just (1975) also develop models which show how institutional factors and market imperfections may lead to risk averse behaviour even when the household is risk neutral.

equation (8). Given (8) there exists four cases for any given level of risk (ψ^2) which depends on whether the good (which is both consumed and produced by the household) is a normal good or inferior good, and whether the net marketed surplus for the good is positive or negative. The results for the following four cases follow the same reasoning used in Finkelshtain and Chalfant for analyzing the effect of a price change.

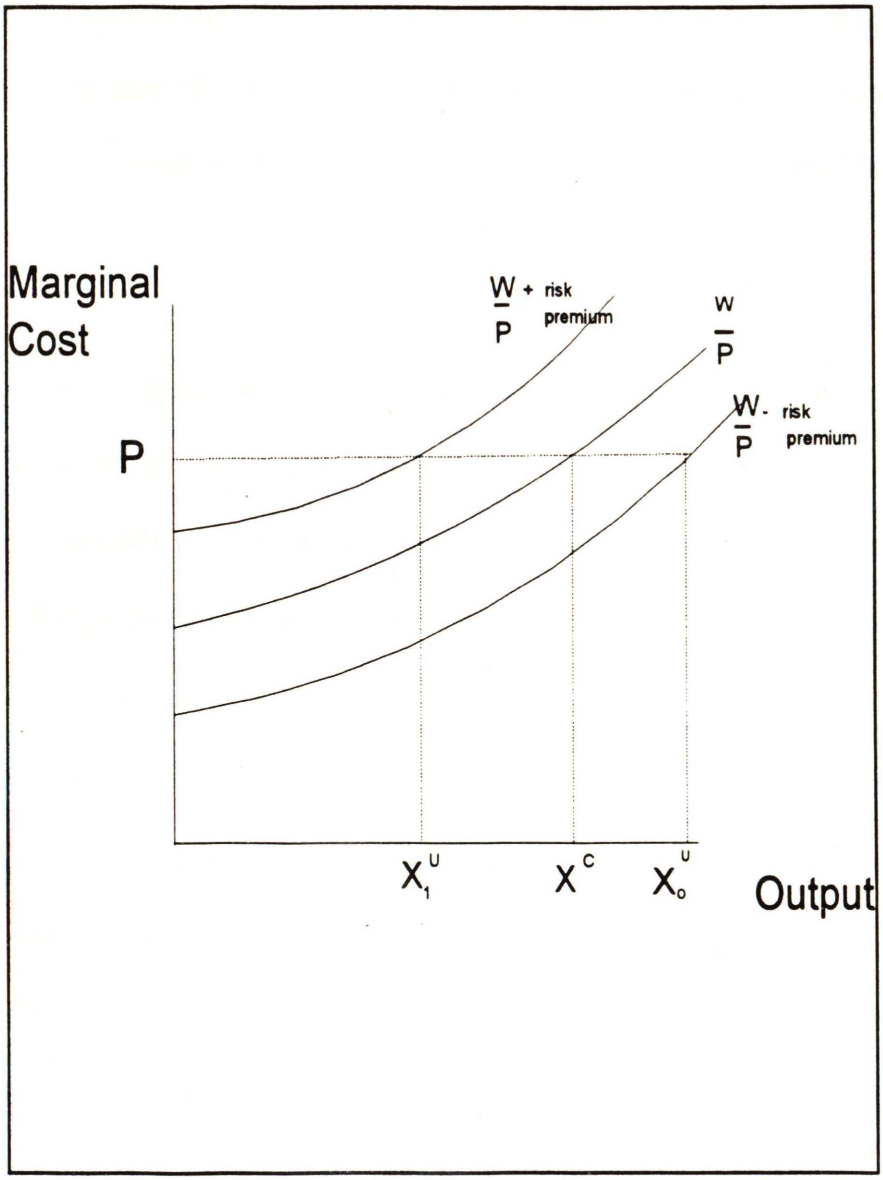
4.3.3 Implications of Risk Aversion for Household Food Availability

The above analysis can be used to determine the effect of increasing risk aversion on the level of output and therefore on household food availability. In the cases to follow it is assumed that the household is risk averse (so that r>0). The analysis is carried out for a given level of home consumption (S) of the home produced good.

CASE I: $\eta > 0$, $X^U > S$ and therefore $r\left(1-\frac{X^U}{S}\right) < 0$

The household is a net seller on the market and its primary concern of optimizing income outweighs its need to produce purely for consumption. Therefore, output is decreasing with respect to an increase in relative risk aversion (r) and this implies that $X^C > X^U$ as can be seen from the following diagram. The difference between price and marginal cost (for $X^U < X^C$) may be attributed to the cost of risk. In this case the income effect dominates the consumption effect. For a given level of consumption, increasing risk aversion would have adverse consequences for the marketed surplus of the household. In this situation, policies designed to aid households in diversifying the production risks they face would have a positive effect on the marketed surplus.

Figure 4.1: The Effect of Risk on Household Production



CASE II: $\eta < 0$, $X^U < S$ and $r\left(1-\frac{X^U}{S}\right) > 0$

In this case the household is a net buyer of an inferior good. Using the same logic as in case I the result is that output is increasing with increasing r and therefore $X^C < X^U$. The consumption effect dominates the income effect. Although production would be greater with uncertain prices than with certain prices, the household still does not meet all of its consumption requirements. The consequences for household food availability would depend on the existence of other sources of income for the household. Attempts to diversify income risk from the production side would not help in increasing the household's ability to produce its own food. In this case diversifying risk from the consumption side through alternative sources of income might be more effective in ensuring food security. Since η is less than zero this good is an inferior good and is primarily consumed by poorer households and the negative net marketed surplus reinforces this so that even though the household is producing this commodity at a loss it continues to produce more to ensure against food insecurity. Alternative sources of income might also lead to an increase in the marginal productivity of labour on the farm. This is especially important in a labour surplus economy (such as Rwanda). If labour supply is rationed then an option that may be open to the government would be to create more job opportunities through public works programs.

CASE III: $\eta < 0$, $X^U > S$ and $r\left(1-\frac{X^U}{S}\right) < 0$

$$\therefore \quad X^U \overset{<}{\underset{>}{=}} X^C \quad as \quad |\eta| \overset{<}{\underset{>}{=}} r\left(\frac{X^U-S}{S}\right)$$

In this case the good is an inferior good and is primarily consumed by poorer households. If η is strongly inferior ($|\eta| >> 1$) then $pf_L-w<0$ and $X^U > X^C$. The return to labour is negative in the short-run. In order to continue producing the household would have to be covering its fixed cost. In this case the household is producing to ensure food security. If $|\eta|$ is small enough then $pf_L-w>0$ and $X^U < X^C$. The income effect dominates and these households do not have to produce beyond the point where the returns to labour is negative in order to ensure food security. Alternative sources of income would be important in ensuring food security. Diversification of risk would improve production levels and improve marketed surplus.

CASE IV: $\eta > 0$, $X^U < S$ and $r\left(1-\frac{X^U}{S}\right) > 0$

$$\therefore \quad X^U \overset{<}{\underset{>}{=}} X^C \quad as \quad \eta \overset{>}{\underset{<}{=}} r\left(1-\frac{X^U}{S}\right)$$

If η is large enough (greater than 1) then $pf_L-w > 0$ and $X^U < X^C$. In this case the good is a luxury. The household is a net purchaser of the commodity. The income effect dominates the consumption effect and the household's food availability will depend on its purchasing power in the market place. The household's ability to grow its food could be improved by its diversifying the risks it faces. However, if η is small enough then $pf_L - w < 0$ and $X^U > X^C$. The commodity is a necessity and the consumption effect dominates. Therefore, the household's ability to meet its consumption requirements depends on alternate sources of income.

Table 4.1: Summary of Effect of Price risk on Household Food Availability by Type of Household

	NET SELLER	NET BUYER
Normal good ($\eta > 0$)	(CASE I) $X^C > X^U$	(CASE IV) $X^U \lesseqgtr X^C$ as $\lvert\eta\rvert \gtreqless r\left(1-\frac{X^U}{S}\right)$
Inferior good ($\eta < 0$)	(CASE III) $X^U \lesseqgtr X^C$ as $\lvert\eta\rvert \lesseqgtr r\left(\frac{X^U-S}{S}\right)$	(CASE II) $X^C < X^U$

The above cases (which are summarized in Table 4.1) show that it is not just the existence of risk that effects household food availability but also the household's response toward the risk. The household's response to the risk will depend on its attitude toward risk, its degree of subsistence orientation and the income elasticity of demand for the good which it also consumes. These cases also show that it is not always the case that aiding the household in diversifying the production risks it faces (from the production side) will lead to improved production and therefore improved household food availability. In the Rwandan case, the goods to be studied include sorghum, maize and potatoes which are normal goods. Income elasticities for staple foods in the study area are positive (Von Braun et. al. 1991:66). The average value of subsistence orientation (S/X^U) over all households is 69% (Ibid:38). Therefore, it is hypothesized that Case I or Case IV is representative of the situation in Rwanda. The pattern of risk attitudes will have an effect on the households' decision to become more commercialized and to adopt new technologies.

4.4 The Model under Price and Production Risk

In order to include production and price risk some simplifying assumptions are necessary so that meaningful results can be derived. Households are assumed to be price takers. Market prices are determined when market demand (Q) equals market supply ($\sum_i X_i$), such that $Q = Q(p) = \sum_i X_i$ where $X_i = f_i(L)$, i=1..n households. Market prices are therefore, a function of market level demand (p(Q)). Define risky revenue (where quantities are the source of variation) as $R' = p'(Q)f'(L)$ with expected value $R = pf(L) + cov(p,f)$[5]. All other inputs are surpressed because they are assumed to be

5 In Rwanda, isolated markets resulting from poor roads, and high transportation costs, contribute to transaction costs. As a result, regional output is highly negatively correlated with regional prices. In addition, there is also a high positive correlation of output across households. This means that production shocks (such as droughts) within a region effects all households in the same way (see Loveridge 1986).

constant for simplicity. The marginal value product of labour is $R'_L=pf_L(L)$ with expected value equal to $R_L=pf_L+cov(p,f_L)$. The second and third moments of revenue may be defined: $var(R)=E[(R'- R)^2]$ and $sk(R)=E[(R'- R)^3]$ respectively[6]. Then the derivative of each moment with respect to labour may be defined as follows:

$$\begin{aligned}\frac{\partial var(R)}{\partial L} &= 2\left(E[(R' - R)(R_L - R_L)]\right) \\ &= 2cov(R, R_L)\end{aligned}$$

and

$$\begin{aligned}\frac{\partial sk(R)}{\partial L} &= 3\left(E[(R' - R)^2(R_L - R_L)\right) \\ &= 3sk(R, R_L)\end{aligned}$$

From the first order condition (6i), **(9)**

$$\frac{pf_L - \dfrac{EU_l}{EU_c}}{pf_L} = \frac{E\{U_Y(p'f'_L - pf_L)\}}{EU_Y pf_L}$$

A Taylor series expansion of (9) about the mean level of output (X) yields (11) (see Appendix 4.2).

---

6 Variance (second moment) is the measure of dispersion about the mean. Skewness (third moment) is the measure of the degree and placement of dispersion relative to the mean. A positively skewed distribution is characterized by more dispersion above the mean. Whereas, a negatively skewed distribution is characterized by more dispersion below the mean.

$$\frac{pf_L - w}{pf_L} = -r\left\{\beta\left(\frac{\epsilon - 1}{\epsilon}\right) + \frac{s_M}{\epsilon}\left(1 + \frac{\eta}{r}\right)\right\}cov(R, R_L) + d\left\{\frac{\beta^2}{2}\left(\frac{\epsilon - 1}{\epsilon}\right)^2\right\}sk(R, R_L)\,Y \tag{10}$$

The first term on the right hand side of equation (10) is a measure of risk aversion whereas the second term is a measure of aversion to downside risk. The measure of relative downside risk aversion is represented by d. If $d=0$, $\epsilon=1$ or $sk(R,R_L)=0$ then only the second moment is important in determining the marginal risk premium. In this case, if the price elasticity of demand is one, then the income effect is zero since a change in output has no effect on revenue. However, the consumption effect would determine the amount of family labour employed on the farm and therefore the level of production.

The risk coefficients in the above derivations are based on expected utility. In order to relate these measures to the utility function, Antle (1987: 514) derives the following conversion factors which are based on the assumption that EU_Y is a second order approximation to U_Y: $AP=\frac{-U_{YY}}{U_Y}Y$, $DS=\frac{U_{YYY}}{U_Y}Y$ with $AP\approx-2r$, $DS\approx 6d$. AP is the Arrow-Pratt measure of relative risk aversion and DS is the measure of downside risk aversion.

In the case of price risk the income effect denoted the change in income when price changed and was measured by the coefficient β. In the present case (of production and price risk) the income effect denotes the change in income when output and therefore prices change: $\beta\left(\frac{\epsilon-1}{\epsilon}\right)$. This effect depends on the price elasticity of demand for the good produced by the household. The consumption effect reflects the change in consumption required to keep marginal utility constant following a change in the quantity produced: $\frac{s_M}{\epsilon}\left(1-\frac{\eta}{I}\right)$. The interpretation of each effect is the same as that of price risk only. However, in the present case, the income effect is positive if the price elasticity of demand is elastic and zero or negative otherwise.

4.5 The Effect of Production Risk on Household Consumption and Labour Allocation

This section outlines the structure of relationships that will be used in studying the effect of production risk on consumption. In the process, some general hypotheses will be developed concerning the way in which risk impacts on household consumption and labour allociation. These hypotheses will form the basis for the empirical model to be estimated for Rwanda.

Assuming production and consumption decisions are interdependent, and using the results of the first order condition (6i and 6ii), the following reduced from may be estimated for the staple (S), and leisure (l).

$S=S(p,p_S,w,var(R),sk(R),Y)$

$l=l(p,p_S,w,var(R),sk(R),Y)$

where, $Y=wT + \Pi(P,var(R), sk(R),K) + I$. Y represents full income which is a function of the risk measures (var(R), sk(R)), P is a vector of prices (p, p_S, w), I is non-labour income or savings, T is the stock of labour time available to the household, and

K is the fixed input to production.

The effect of risk on household labour allocation may be discerned by using (6i) and 6(vi) and substituting EU_{OF} and EU_L for EU_l. This yields:

(11)

$$\frac{pf_L}{\hat{w}} - \frac{EU_L}{EU_{OF}} = \frac{cov(U_C, pf_L)}{\hat{w}EU_C}$$

where, $\hat{w}$ is the shadow value of labour allocated off-farm. Let m represent the marginal rate of substitution between family labour allocated on-farm (L) and off-farm (OF) so that $m \equiv \frac{EU_L}{EU_{OF}}$. Then one can write m as a function of the relative price between farm and off-farm labour (which will be referred to as the terms of trade between farm and off-farm labour -- TM), and the marginal risk premium with respect to family labour employed on the farm (MRP_L). The term on the right hand side of equation (11) represents the MRP_L. This marginal risk premium is also a function of the terms $cov(R,R_L)$, $sk(R,R_L)$, var(R) and sk(R). Therefore, one can write:

$$m=m(TM, var(R), sk(R), cov(R,R_L), sk(R,R_L)).$$

The model therefore is comprised of the following equations:

$S=S(p,p_S,w,var(R),sk(R),Y)$	household food demand
$l=l(p,p_S,w,var(R),sk(R),Y)$	household leisure demand
$m=m(TM,var(R),sk(R),cov(R,R_L),sk(R,R_L))$	household labour allocation.

An increase in TM means an increase in the productivity on-farm labour (pf_L) relative to off-farm labour ($\hat{w}$), therefore, relatively more labour will be allocated on the farm: $\frac{\partial m}{\partial TM}>0$. The effect of an increase in the level of risk and downside risk on labour allocation between farm and off-farm activities depends on whether family labour is risk and downside risk increasing or decreasing. If family labour is risk decreasing in farm production then cov(R,R_L) will be less than zero and an increase in risk will lead to more labour allocated on the farm. If family labour is downside risk decreasing then sk(R,R_L) will be positive and an increase in downside risk will lead to more labour allocated toward on-farm activities.

Let P_i be an element in the price vector P with elements (p,p_S,w) and X_i be an element in the vector X with elements (S,l), E is total household expenditure.
The comparative static effect of a price change in the presence of risk on household consumption may be derived as follows (see also Singh, Squire, and Strauss 1986):

(12)

$$\frac{\partial X_i}{\partial P_i} = \frac{\partial X_i}{\partial P_i}\bigg|_{\pi} + \frac{\partial X_i}{\partial Y_{CE}}\frac{\partial Y}{\partial P_i}$$

where for a given level of time T available in the household, and a fixed level of non-labour income. Certainty equivalent income is defined as $Y_{CE} = \bar{Y} - \frac{var(R)}{2}r - \frac{sk(R)}{6}a$

and it is assumed that households maximize certainty equivalent income but, choose the level of consumption such that expenditures equal expected income. The risk premium is $rp = \frac{AP}{2}var(R) - \frac{DS}{6}sk(R)$, where AP is the Arrow-Pratt measure of risk aversion and Ds is the measure of downside risk aversion. The effect of price on certainty equivalent income may be represented as :

$$\frac{\partial Y_{CE}}{\partial p} = \frac{\partial Y}{\partial p} - \left\{\frac{AP}{2}\frac{\partial var(R)}{\partial p} - \frac{DS}{6}\frac{\partial sk(R)}{\partial p}\right\}$$

An increase in price may increase (decrease) the risk premium (rp) depending on whether $\frac{\partial var(R)}{\partial p} \gtrless \frac{\partial sk(R)}{\partial p}$. If the household has protection against downside risk, then $\frac{\partial rp}{\partial p} < 0$ and the income effect is more positive or less negative. The partial derivative $\frac{\partial rp}{p}$ is also analogous to the compensation required to keep marginal utility constant when price changes (see Appendix 3.2).

The first term on the right hand side of (12) gives rise to the usual consumer result:

(13)

$$\frac{\partial X_i}{\partial P_i}\Big|_{\pi} = \frac{\partial X_i}{\partial P_i}\Big|_{\bar{U}} - \frac{\partial E}{\partial P_i}\frac{\partial X_i}{\partial Y}$$

and substituting (13) into (12) yields,

(14)

$$\frac{\partial X_i}{\partial P_i} = \frac{\partial X_i}{\partial P_i}\Big|_{\bar{U}} - \frac{\partial E}{\partial P_i}\frac{\partial X_i}{\partial Y} + \frac{\partial X_i}{\partial Y}\frac{\partial Y_{CE}}{\partial P_i}$$

which is the usual result of the effect of prices on consumer demand. Table 4.2 summarizes the results for the effect of prices on household consumption of S and l. The subsitution effect is the same as in the usual model of consumer decision making. The income effect, however, is made up of two parts: the usual income effect arising from a change in expenditure when prices change and an additional output effect which impacts on income. Therefore, sign of the net income effect depends on whether the household is a net seller or buyer of the good in question and on the level of risk and the household's attitude toward this risk. In the case of a normal good, the income effect is negative if the household is a net buyer. If the household is a net seller, the sign of the income effect depends on the magnitude of the effect of price on the risk premium relative to the effect of price on the net marketed surplus effect. If the risk premium effect outweights the net marketed surplus effect then the income effect is negative, other wise it is positive. Assuming the household is risk averse, the total effect of a price change on the good consumed will be negative if the household is a net buyer or completely self-sufficient. The total effect will be ambiguous if the household is a net seller, and will depend on the sign and magnitude of the income effect.

If one considers the transaction costs which drive a wedge between the prices households pay and receive for the goods they produce then the income effect of a change in the price paid by the household is greater than the income effect of a change in the price received by the household. This can be seen from the following illustration. Following Goetz (1992), the link between prices paid and recieved by households for the good they both produce and consume may be represented as:

$p_s = p^*(1+\tau)$ for buyer a household,

$p_s = p/(1+\tau)$ for seller a household.

In this case, the output effect of a change in the price paid by the household, which differs from the output effect arising from a change in the price received by the household ($\frac{\partial\pi}{\partial p}\frac{\partial S}{\partial Y} = Q\frac{\partial S}{\partial Y}$), may then be written as:

$$\frac{\partial\pi}{p}\frac{\partial p}{\partial p_s}\frac{\partial S}{\partial Y} = \frac{Q}{1+\tau}\frac{\partial S}{\partial Y} \qquad \text{for buyer households,}$$

$$\frac{\partial \pi}{\partial p}\frac{\partial p}{\partial p_s}\frac{\partial S}{\partial Y} = Q\,(1+\tau)\frac{\partial S}{\partial Y}$$ for seller households.

Similarly, the expenditure effect of a change in the price received by the household will now be different from the usual expenditure effect without transaction costs $(\frac{\partial E}{\partial p}\frac{\partial S}{\partial Y} = S\frac{\partial S}{\partial Y})$:

$$\frac{\partial E}{p_s}\frac{\partial p_s}{\partial p}\frac{\partial S}{\partial Y} = S(1+\tau)\frac{\partial S}{\partial Y}$$ for buyer households,

$$\frac{\partial E}{\partial p_s}\frac{\partial p_s}{\partial p}\frac{\partial S}{\partial Y} = \frac{S}{(1+\tau)}\frac{\partial S}{\partial Y}$$ for seller households.

The effect of risk on household consumption of the subsistent crop and on the level of leisure was estimated in a similar manner:

(15)

$$\frac{\partial X_i}{\partial var(R)} = \frac{\partial X_i}{\partial var(R)}\Big|_Y + \frac{\partial X_i}{\partial Y}\frac{\partial Y}{\partial var(R)}$$

$$\frac{\partial X_i}{\partial var(R)}\Big|_Y = \frac{\partial X_i}{\partial var(R)}\Big|_{\bar{U}} - \frac{\partial E}{\partial var(R)}\frac{\partial X_i}{\partial Y}$$

The effect of risk on certainty equivalent income may be derived as follows: $\frac{\partial Y_{CE}}{\partial var(R)} = -\frac{r}{2} - \frac{var(R)}{2}\frac{\partial r}{\partial var(R)}$, for a mean preserving spread and $\frac{\partial Y_{CE}}{\partial sk(R)} = -\frac{d}{6} - \frac{sk(R)}{6}\frac{\partial d}{\partial sk(R)}$, for a mean-variance preserving spread (Menezes, Geiss and Tressler 1980). If one assumes that the household chooses expenditures such that it is equal to expected income then $\frac{\partial E}{\partial var(R)}$ will be equal to zero.[7] The derivative $\frac{\partial X_i}{\partial var(R)}|_{\bar{U}}$ may be evaluated by dividing it into two parts (see Appendix to Chapter 3):

$$\frac{\partial X_i}{\partial var(R)}|_{\bar{U}} = \frac{\partial X_i}{\partial var(R)}|_{U_Y} + \frac{\partial X_i}{\partial U_Y}\frac{\partial U_Y}{\partial var(R)} \tag{16}$$

The left handside of the above equation is analagous to the Hicksian substitution effect and may be termed the general substitution effect. The first term on the right handside is the specific substitution effect (see Phlips). The second term on the right hand side is the compsensation required to keep the marginal utility of income constant when the variance of production changes. Appendix 4.2 shows that $\frac{\partial X_i}{\partial U_Y}$ is the slope of the Frischian demand curves (which is the constant marginal utility of demand curve). The second term on the right hand side of (16) is less than zero if X_i is a normal good[8] and may be looked upon as a income effect. For the good produced and consumed by the household an increase in the variance of production yields:

7

$$E = Y = Y_{CE} + \frac{var(R)}{2}r + \frac{sk(R)}{6}d$$

$$\frac{\partial E}{\partial var(R)} = \frac{\partial Y_{CE}}{\partial var(R)} + \frac{r}{2} + \frac{var(R)}{2}\frac{\partial r}{\partial var(R)} = 0$$

since

$$\frac{\partial Y_{CE}}{\partial var(R)} = -\frac{r}{2} - \frac{var(R)}{2}\frac{\partial r}{\partial var(R)}$$

8 From Appendix 4.2 (see also Besley):

$$\mu_i = \frac{\eta_i}{r} = \frac{\partial X_i}{\partial U_Y}\frac{U_Y}{X_i}.$$

(17)

$$\frac{\partial s}{\partial var(R)} = \frac{\partial s}{\partial var(R)}\bigg|_{U_Y} + \frac{\partial s}{\partial U_Y}\frac{\partial U_Y}{\partial var(R)} + \frac{\partial s}{\partial Y_{CE}}\frac{\partial Y_{CE}}{\partial var(R)}$$

The first term on the right hand side is the specific substitution effect which is negative. The other terms on the right hand side make up the income effect. The income effect has two components: the compensation required to keep marginal utility constant and the change in certainty equivalent income when the degree of variation changes. For a normal good, the sign of the income effect depends on the sign of $\frac{\partial Y_{CE}}{\partial var(R)}$. If the household is risk averse (AP=-2r>0), and assuming $\frac{\partial r}{\partial var(R)} \geq 0$ [9] then production risk will have an unambigous negative effect on the level of household consumption ($\frac{\partial X_i}{\partial var(R)} < 0$).

Similarly, the effect of a change in the degree of downside risk (skewness) on the level of consumption may be written as follows: (18)

$$\frac{\partial X_i}{\partial sk(R)} = \frac{\partial X_i}{\partial sk(R)}\bigg|_{U_Y} + \frac{\partial X_i}{\partial U_Y}\frac{\partial U_Y}{\partial sk(R)} + \frac{\partial X_i}{\partial Y}\frac{\partial Y_{CE}}{\partial sk(R)}$$

As in the previous case, the first term on the right hand side is the specific substitution effect and is negative. The second term is the compensation required to keep marginal utility constant, which unlike the previous case, is positive for a normal good. It is assumed that increasing the skewness (or the probability of a low level of income) will

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[9] This implies constant or increasing risk aversion as the variance in income increases.

increase the marginal utility derived from a given level of income. In the Rwandan case, it is assumed that the distribution of production will be positively skewed (sk(R) > 0).[10] The sign of the derivative $\frac{\partial Y_{CE}}{\partial sk(R)}$ is less than zero, and $\frac{\partial d}{\partial sk(R)} \geq 0$. Increasing the positive skewness of the distribution in production increases the aversion to downside risk. The result is that the effect of a decrease in downside risk (an increase in the positive skewness) on household consumption is ambiguous. The sign of this effect depends on the magnitude of the compensation required to keep marginal utility constant:

(19)

$$\frac{\partial X_i}{\partial sk(R)} \geq 0 \quad as \quad \frac{\partial X_i}{\partial U_Y}\frac{\partial U_Y}{\partial sk(R)} \geq \left| \frac{\partial X_i}{\partial sk(R)}\bigg|_{U_Y} + \frac{\partial X_i}{\partial Y}\frac{\partial Y_{CE}}{\partial sk(R)} \right| \qquad (i)$$

$$\frac{\partial X_i}{\partial sk(R)} < 0 \quad as \quad \frac{\partial X_i}{\partial U_Y}\frac{\partial U_Y}{\partial sk(R)} < \left| \frac{\partial X_i}{\partial sk(R)}\bigg|_{U_Y} + \frac{\partial X_i}{\partial Y}\frac{\partial Y_{CE}}{\partial sk(R)} \right| \qquad (ii)$$

The level of compensation depends on whether the household's subsistence requirements is above or below the probable level of production. Assuming sk(R) > 0, and given an increase in the skewness (in other words, an increase in the probability of some low level of production) will have different effects on the household's marginal utility depending on whether the household's requirements are above or below the probable level of production. If the household's requirements are below the probable level of production,

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10 A positively skewed distribution reflects the adverse production situation in the study area (see also the study by Antle and Crissman 1990:523 for the Philippines). This means that the probability of a low level of production is greater than the probability of achieving a high level of production.

then (19i) is the case. Therefore, increasing the skewness will increase marginal utility to a greater extent than it would if the household's requirements were above the probable level of production (19ii would be the result in this case). Table 4.3 summarizes these results.

4.6 Summary

This chapter has outlined the theoretical framework to be used in estimating the effect of production risk on household consumption. The framework incorporates risk in a static household model. The effect of price on household food availability depends on whether the in question is a normal good and whether the household is net buyer or net seller. It is expected that production risk will have an unambiguous negative effect on household consumption. The effect of skewness on household consumption is ambiguous and depends on how low the level of output to which the mass of the distribution is concentrated. The effect of risk on labour allocation between farm and off-farm activities depends on whether family labour is risk and downside risk increasing or decreasing. It is expected that if labour is risk increasing then an increase in the level of risk will lead to less labour allocated on the farm. Similarly, if labour is downside risk increasing then, an increase in the level of downside risk will lead to more labour allocated to off-farm activities. These hypotheses will be examined in the Rwandan case.

Table 4.2: The Effect of Price Changes (in the presence of production risk) on Household Consumption

Exogeneous Variables	Household Food Consumption (S)	Household Leisure Consumption (l)	Labour Allcation (m)
Sales Price of Food (P)			
net seller	$\frac{\partial S}{\partial P}\Big\vert_{\bar{U}} + \left(Q - \frac{S}{1+\tau} - \frac{\partial rp}{\partial p}\right)\frac{\partial S}{\partial Y} \gtrless 0$	$\frac{\partial l}{\partial P}\Big\vert_{\bar{U}} + \left(Q - \frac{S}{1+\tau} - \frac{\partial rp}{\partial p}\right)\frac{\partial l}{\partial Y} \gtrless 0$	
net buyer	$\frac{\partial S}{\partial P}\Big\vert_{\bar{U}} + \left(Q - S(1+\tau) - \frac{\partial rp}{\partial p}\right)\frac{\partial S}{\partial Y} < 0$	$\frac{\partial l}{\partial P}\Big\vert_{\bar{U}} + \left(Q - S(1+\tau) - \frac{\partial rp}{\partial p}\right)\frac{\partial l}{\partial Y} < 0$	
Purchase Price of Food (P_s)			
net seller	$\frac{\partial S}{\partial P_s}\Big\vert_{\bar{U}} + \left(Q(1+\tau) - S - \frac{\partial rp}{\partial p}(1+\tau)\right)\frac{\partial S}{\partial Y} \gtrless 0$	$\frac{\partial l}{\partial P_s}\Big\vert_{\bar{U}} + \left(Q(1+\tau) - S - \frac{\partial rp}{\partial p}(1+\tau)\right)\frac{\partial l}{\partial Y} \gtrless 0$	
net buyer	$\frac{\partial S}{\partial P_s}\Big\vert_{\bar{U}} + \left(\frac{Q}{1+\tau} - S - \frac{\partial rp}{\partial p}\frac{1}{1+\tau}\right)\frac{\partial S}{\partial Y} < 0$	$\frac{\partial l}{\partial P}\Big\vert_{\bar{U}} + \left(\frac{Q}{1+\tau} - S - \frac{\partial rp}{\partial p}\frac{1}{1+\tau}\right)\frac{\partial l}{\partial Y} < 0$	
Market wage rate* (w)			
net seller	$\frac{\partial S}{\partial w}\Big\vert_{\bar{U}} + (T - L - l)\frac{\partial S}{\partial Y} \gtrless 0$	$\frac{\partial l}{\partial w}\Big\vert_{\bar{U}} + (T - L - l)\frac{\partial l}{\partial Y} \gtrless 0$	
net buyer	$\frac{\partial S}{\partial w}\Big\vert_{\bar{U}} + (T - L - l)\frac{\partial S}{\partial Y} < 0$	$\frac{\partial l}{\partial w}\Big\vert_{\bar{U}} + (T - L - l)\frac{\partial l}{\partial Y} \gtrless 0$	
Terms of Trade between farm and off farm labour (TM)			$\frac{\partial m}{\partial TM} > 0$
Household Income (Y)	$\frac{\partial S}{\partial Y} > 0$	$\frac{\partial l}{\partial Y} > 0$	

Note: * It is assumed that $\frac{\partial rp}{\partial w} = 0$.

Table 4.3: The Effect of Production Risk on Household Food Consumption and Labour Allocation

Exogeneous Variables	Household Food Consumption (S)	Household Leisure Consumption (l)	Labour Allocation between farm and off-farm Activities (m)
var(R)	$\frac{\partial S}{\partial var(R)} < 0$	$\frac{\partial l}{\partial var(R)} < 0$	$\frac{\partial m}{\partial var(R)} \gtrless 0$ as $\frac{\partial var(R)}{\partial L} \lessgtr 0$
sk(R)	$\frac{\partial S}{\partial sk(R)} \lessgtr 0$ as $\frac{\partial S}{\partial U_Y}\frac{\partial U_Y}{\partial sk(R)} \lessgtr \left\| \frac{\partial S}{\partial sk(R)}\Big\|_{U_Y} + \frac{\partial S}{\partial Y}\frac{\partial Y_{CE}}{\partial sk(R)} \right\|$	$\frac{\partial l}{\partial sk(R)} \lessgtr 0$ as $\frac{\partial l}{\partial U_Y}\frac{\partial U_Y}{\partial sk(R)} \lessgtr \left\| \frac{\partial l}{\partial sk(R)}\Big\|_{U_Y} + \frac{\partial l}{\partial Y}\frac{\partial Y_{CE}}{\partial sk(R)} \right\|$	$\frac{\partial m}{\partial sk(R)} \gtrless 0$ as $\frac{\partial sk(R)}{\partial L} \gtrless 0$

Note: $\frac{\partial Y_{CE}}{\partial var(R)} = \left(-\frac{r}{2} - \frac{var(R)}{2}\frac{\partial r}{\partial var(R)}\right)$ **for a mean preserving spread; and** $\frac{\partial Y_{CE}}{\partial sk(R)} = \left(-\frac{d}{6} - \frac{sk(R)}{6}\frac{\partial d}{\partial sk(R)}\right)$ **for a mean-variance preserving spread.**

Appendix 4.1

The first order condition yields:

$$E\{-U_l + U_C p f_L\} = 0. \tag{A4.1.1}$$

This can be rewritten as:

$$\begin{aligned} &-EU_l + EU_C\, pf_L - f_L\, cov(U_C, p') = 0 \\ &= -EU_l + EU_C\, pf_L - f_L E\{(U_C - \bar{U}_C)(p' - p)\} \\ &= -EU_l + EU_C\, pf_L - f_L E\{U_C(p' - p)\} \end{aligned} \tag{A4.1.2}$$

Full income is defined as follows:

$$\begin{aligned} Y &\equiv \pi^*[p, p_C, \hat{w}_F, \hat{w}_M, w; NW^*] + \hat{w}_F T_F + \hat{w}_M T_M \\ &= \hat{w}_F l_F + \hat{w}_M l_M + pS^* + p_C C^* + p_{HT} HT^* \end{aligned} \tag{A4.1.3}$$

From the first order conditions, at the optimum solution $EU_Y(P,Y) = EU^*_C/p_C$.

Therefore, a third order Taylor series expansion of the marginal utility of income about expected price (p) yields:

$$\begin{aligned} U_C &= U_Y \\ &\approx U(Y,p) + U_{YP}(p' - p) + U_{YY}(p' - p)\frac{\partial Y}{\partial p} + \frac{1}{2}U_{YPP}(p' - p) \\ &\quad + \frac{1}{2}U_{YPY}(p' - p)^2\frac{\partial Y}{\partial p} + \frac{1}{2}U_{YYP}(p' - p)^2\frac{\partial Y}{\partial p} \\ &\quad + \frac{1}{2}U_{YYY}(p' - p)^2\left(\frac{\partial Y}{\partial p}\right)^2 \end{aligned} \tag{A4.1.4}$$

Using Roy's identity (Newberry and Stiglitz 1981) one can derive the expressions $U_{YP} = -S_Y U_Y - SU_{YY}$ and $U_{YPY} = -S_{YY}U_Y - 2S_Y U_{YY} - SU_{YYY}$. It is assumed that $U_{YPY} = U_{YYP}$ and that S_{YY} and U_{YPP} are close to zero. Therefore,

(A4.1.5)

$$U_Y \approx$$
$$U_Y(Y,p) + \left(U_{YY}Y\frac{\partial Y}{\partial p}\frac{p}{Y} + \left(-\frac{\partial S}{\partial Y}\frac{Y}{S}U_Y\frac{pS}{Y} - \frac{pS}{Y}U_{YY}Y\right)\right)\left(\frac{p'-p}{p}\right)$$
$$+ \left(-2\frac{\partial S}{\partial Y}\frac{Y}{S}\frac{pS}{Y}U_{YY} - \frac{pS}{Y}U_{YYY}Y\right)\frac{\partial Y}{\partial p}\frac{p}{Y}\, Y\left(\frac{p'-p}{p}\right)^2$$
$$+ \frac{1}{2}U_{YYY}Y\left(\frac{\partial Y}{\partial p}\frac{p}{Y}\right)^2 Y\left(\frac{p'-p}{p}\right)^2$$

Multiplying both sides of the above expression by (p'-p)/pf_L and taking expectations yields:

(A4.1.6)

$$\frac{f_L E\{U_Y(p'-p)\}}{pEU_Y} = \{r\beta + (s_M r - \eta s_M)\}E\left\{\left(\frac{p'-p}{p}\right)^2\right\}$$
$$+ \left\{\left(-2\eta s_M\frac{r}{Y} - s_M d\right)\beta + \frac{1}{2}d\beta^2\right\}E\left\{\left(\frac{p'-p}{p}\right)^3\right\}Y$$

where Y is the mean level of income. Taking $2\eta s_M\frac{r}{y} \approx 0$,

and noting that $w = EU_l/EU_C$ and if the household is risk averse ($r = \{EU_{YY}/EU_Y\}Y < 0$), averse to down side risk ($d = \{EU_{YYY}/EU_Y\}Y > 0$) and consumes a normal good ($\eta > 0$) then

(A4.1.7)

$$\frac{pf_L - w}{pf_L} = \left\{r\beta + s_M\left(1 + \frac{\eta}{r}\right)\right\}\frac{var(p')}{p^2} + d\beta^2\left\{\frac{1}{2} - \frac{s_M}{\beta}\right\}Y\frac{sk(p')}{p^3}$$

From the above equation one can see that the risk premium has two parts: the first is the premium associated with aversion to risk; and the second is the part of the premium assoicated with aversion to downside risk. If it is assumed that prices are fully characterized by a two moment distribution then sk(p') will be equal to zero and the risk premium (represented by the first term on the right hand side of the equation) only reflects the aversion to risk. The different possibilities for this case have been analyzed in the text.

However, if the third moment of prices significantly contributes to the characterization of the distribution of prices then the risk premium is made up of the two parts described above. With respect to downside risk aversion, if the distribution of prices are negatively skewed then risk is transfered from the right of the mean (or target) price to the left of the mean (or target) price. It is assumed that $d>0$, therefore, both households prefer distributions with less downside risk to that of more downside risk. However, the impact of the risk on the household's decision making process will depend on whether the household is a commerical or subsistent household. In the second term on the right hand side of the above equation, if $\beta=1$ so that the household acquires all of its income from agricutlural production then if s_M is less than one half (which is Wharton's definition of a commerical household) then the risk premium associated with downside risk aversion is negative. For the commercial household, a negatively skewed price distribution has a postive impact on its decision rule because the lower risk assoicated with prices above the target price outweigh the higher risk associated with prices below the target price. If s_M is greater than one half (subsistent household) then the risk premium assoicated with downside risk is positive. The subsistent household sees the higher level of downside risk as a cost. These households are more concerned with falling below some target level of price than the commerical households.

Appendix 4.2

In order to derive the amount that expenditures must change in order to keep marginal utility constant Besley (1989) defines a production function for consumption:

$g(p,q) \equiv \text{Max } qU(S) - pS$ **(A4.2.1)**

where, $q \equiv V_Y\ (p,Y)$ is the marginal utility of income and V(.) is the indirect utility function derived from maximizing U(S) subject to an income constraint. Applying Hotelling's lemma to g(p,q) Besley derives the Frischian demand curves (unrestricted demand curves -- both utility and income are not constrained):

(A4.2.2)

$$\frac{\partial g(p,q)}{\partial p} = -S^F(p,q)$$

Besley then defines

(A4.2.3)

$$\mu \equiv \frac{\partial \log\ S^F(p,q)}{\partial \log\ q}$$

given μ a relationship between this elasticity and the Marshallian income elasticity is derived. At the optimum: $S^F[p, V_Y[p,Y]^{-1}] \equiv S^M[p,Y]$ when both sides are differentiated with respect to Y the result is $\mu = \frac{\eta}{r}$. Therefore, given prices p, the expenditures requied to keep an individual at a constant utility of income across various risky states of the world is revenue less the profits of utility at q.

$E[p,q] = q\ g_q[p,q] - g[p,q]$ and

$g_q = q\ U_S\ S_q + U[S[p,q]] - p\ S_q$ but $U_S = 0$ since q is constant therefore,

$$E[p,q] = qU - qpS_q - qU + pS$$

$$\begin{aligned}\frac{\partial E}{\partial p}\cdot\frac{p}{E} &= -\frac{pS}{E}\cdot\frac{q}{S}\cdot\frac{\partial S}{\partial q}+\frac{pS}{E}\\ &= s_M(1-\mu)\\ &= s_M\left(1-\frac{\eta}{r}\right)\end{aligned}$$

where $s_M=\frac{pS}{E}$, *and E is total expenditure*

Appendix 4.3

The left hand side of (9) may be written in a more meaningful way. A Taylor series expansion of U_Y about X yields:

(A4.3.1)

$$\begin{aligned} U_Y &= U_Y(X) \\ &+ \left\{U_{YY}\frac{\partial Y}{\partial R}\frac{\partial R}{\partial X} + U_{YP}\frac{\partial p}{\partial X}\right\}(X' - X) \\ &+ \frac{1}{2}\left\{(U_{YYP} + U_{YPY})\frac{\partial Y}{\partial R}\frac{\partial R}{\partial X}\frac{\partial p}{\partial X} + U_{YPP}\left(\frac{\partial p}{\partial X}\right)^2 + U_{YYY}\left(\frac{\partial Y}{\partial R}\frac{\partial R}{\partial X}\right)^2\right\}(X' - X)^2 \end{aligned}$$

Since these are agricultural households, producing mainly for consumption, it is assumed that households are concerned with downside risk associated with income and not downside risk associated with prices. Therefore, setting $U_{YPP} = U_{YPY} = U_{YYP} = 0$, using Roy's identity (see Appendix 4.1) yields:

(A4.3.2)

$$\begin{aligned} U_Y &= U_Y(X) \\ &+ \left\{U_{YY}Y\frac{\partial Y}{\partial R}\frac{R}{Y}\frac{\partial R}{\partial X}\frac{X}{R} + (-S_Y\frac{Y}{S}\frac{pS}{Y}U_Y - \frac{pS}{Y}U_{YY}Y)\frac{\partial p}{\partial X}\frac{X}{p}\right\}\frac{(X' - X)}{X} \\ &+ \left\{\frac{1}{2}U_{YYY}Y\left(\frac{\partial Y}{\partial R}\frac{R}{Y}\frac{\partial R}{\partial X}\frac{X}{R}\right)^2\right\}\frac{(X' - X)^2}{X^2} \end{aligned}$$

Taking X=f(L), the expression $\frac{\partial R}{\partial X}\frac{X}{R}$ may be evaluated as follows:

(A4.3.3)

$$dR = \left(\frac{\partial p}{\partial X}dX\right)X + pdX + \frac{\partial cov(p(X), X)}{\partial X}dX$$

$$and$$

$$\frac{dR}{dX}\frac{X}{px} = \frac{\partial p}{\partial X}\frac{X}{p} + 1$$

$$\therefore \quad \epsilon_R = 1 - \frac{1}{\epsilon}$$

where ϵ is the price elasticity of demand.

and $\frac{\partial Y}{\partial R}$ is assumed to be equal to one. Cov(p(X),X) is assumed constant for a given technology. If there is no correlation between individual producer output and market output then $\frac{\partial p}{\partial X}=0$. Multiplying (10) by $\frac{(p'f'_L - pf_L)}{EU_Y pf_L}$ and taking expectations yields the right hand side of equation (A4.3.2):

(A4.3.4)

$$\frac{E\{U_Y(p'f_L - pf_L)\}}{pf_L EU_Y} = \left\{r\beta\left(1-\frac{1}{\epsilon}\right) + \frac{s_M}{\epsilon}(\eta + r)\right\}E\left\{\frac{(X' - X)}{X}\frac{(p'f'_L - pf_L)}{pf_L}\right\}$$
$$+\left\{\frac{1}{2}d\left(\beta\left(1 - \frac{1}{\epsilon}\right)\right)^2\right\}YE\left\{\frac{(X' - X)^2}{X^2}\frac{(p'f_L - pf_L)}{pf_L}\right\}$$

defining $r=\frac{EU_{YY}}{EU_Y}Y$, $d=\frac{EU_{YYY}}{EU_Y}Y$, taking r/y close to zero, $EU_l/EU_C=w$, and multiplying and dividing the term (X' - X)/X by p yields equation (11) in the text.

CHAPTER FIVE
THE ECONOMETRIC MODEL WITH SOME STATISTICAL CONSIDERATIONS

5.1 Introduction

This chapter is divided into three sections. The first section examines the empirircal model along with the statistical considerations used to estimate production risk, risk preferences and the effect of this risk on household consumption and labour allocation. The second section briefly describes the data set used and the construction of the key variables to be used in the estimations. The last section concludes the chapter.

5.2 Estimating the Effect of Production Risk on Consumption

The empirical model will be outlined in this section. The section is divided into three sub-sections. In the first sub-section, Antle's moment based approach, which is used to estimate the level of production risk in the study area, is outlined. The second sub-section outlines how these estimates are to be used in estimating risk preferences of households. The equation which relates prices received to prices paid by households is discussed in the third sub-section. In the last sub-section, the equations to be used in estimating the effect of production risk on consumption are outlined.

5.2.1 The Moment Based Approach to Estimating Production Risk

In the moment based approach to the estimation of the probability distribution of output the moments of output are assumed to be related to input decision variables.

The three moment approximation to the distribution of production will be consistently estimated using the methods outlined in Antle (1988). The value of production is used in order to allow prices and quantities to vary jointly. The moment functions will be specified as quadratic functions of the inputs to production.

The steps for estimating the moments of production are as follows:

1) The regression $Q_j = X_j\beta_j + e_{1j}$ is estimated

where, Q_j is output for the jth household and X_j is a vector containing the quadratic expansion of inputs: seed, labour, land, tools, animal inputs and chemical inputs.

2) The residuals from 1) are squared and the following regression is estimated

$$e^i_{1j} = X_j\beta_j + e_{ij} \qquad i=2,3$$

where i refers to the second and third moments.

3) The weights to be used in the Generalized Least Squares (GLS) estimation is derived by taking the residuals from 2) and performing the following regression

$$e^2_{ij} = X_j\gamma_j + v_{ij} \qquad i=1,2,3.$$

The square root of the predicted values from 3) are used as weights in re-estimating 1) and 2). Antle (1983;1988) suggests that in order to ensure that the predicted value for the even moments are positive that the regression in 3) should be performed with a linear programming package with the restriction that the $X_j\gamma_j > 0$. Alternatively, one may employ the estimator suggested by White(1980). White suggests assigning an arbitrarily small positive number to those predicted variances which are negative. This procedure for correcting for heteroscedasticity is consistent and simpler to apply than the method suggested by Antle and is the procedure to be employed in this study.

5.2.2 Estimating Household Attitudes toward Risk

The model to be used in estimating risk preferences and testing for whether labour supply off-farm is rationed is based on equation (10) in Chapter 4. Unlike Antle, labour will be dissaggregated according to male, female family labour and hired labour:

$$pf_L = b_0 + b_1 W + b_2 \frac{cov(R,R_L)}{R\,R_L} + b_3 \frac{sk(R,R_L)}{R^2 R_L} + u$$
$$b'_i = b + v_i,\quad i=2,3;$$
$$E(v_i)=0;\, E(v_i,v_j)=\Delta \text{ and;}$$
$$u = v_0 + v_1 \frac{cov(R',R_L)}{RR_L} + v_2 \frac{sk(R',R_L)}{R^2 R_L} + e$$

where, pf_L is the marginal value product of labour,

W is the market wage rate,

$cov(R,R_L)$ and $sk(R,R_L)$ are respectively the derivative of the second and third moment of production with respect to labour (see section 4.4 of Chapter 4).

The (nx1) vector u, is the heterscedastic error term for the above equation and the error term e has the usual OLS properties. Following (Jacoby) and using the results from the FOCs it is hypothesized that if the market wage rate is not equal to the marginal value product of labour then labour supply is rationed. This means that shadow wages for the household are endogenously determined. If labour is rationed then the possibility of diversifying risk through off-farm sources of income are limited. One can test for the endogeneity of wages with the joint test of the coefficients H:$b_0=0$ and $b_1=1$.

It is hypothesized that $E(v_i,v_j)$ is not equal to zero because of variation in risk preferences across households. Risk preferences may vary across households as a result of variation in the level of wealth, and also as a result of variation in the structure of the household. Two stage least squares (TSLS) will be the method used in order to account for this variation (Antle 1989). The coefficients b_2 and b_3 may be restricted to be equal across the system of equations. This equation will be used to derive the coefficient of relative risk aversion (r) and the coefficient of relative downside risk aversion (d). From Chapter 4 equation (10) in the text:

$$b_2 = r\left\{\beta\left(\frac{\epsilon-1}{\epsilon}\right) + \frac{s_M}{\epsilon}\left(1+\frac{\eta}{r}\right)\right\}$$
$$b_3 = d\left\{\frac{\beta^2}{2}\left(\frac{\epsilon-1}{\epsilon}\right)^2\right\}$$

The above coefficients of risk aversion are expressed in terms of expected utility. In order to convert them to the equivalent Arrow-Pratt measures Antle derives the conversion factor: AP=-2r, DS=6d, where AP, and DS are respectively the measures of relative risk and downside risk aversion expressed in utility as opposed to expected utility terms.

After estimating the parameters r and d, the risk premium as a percentage of revenue may be estimated as follows:

$$\frac{\rho}{Y} = \frac{VAR(R)}{Y}r - \frac{SK(R)}{Y}d$$
$$= \frac{VAR(R)}{Y}\frac{AP}{2} - \frac{SK(R)}{Y}\frac{DS}{6}.$$

The above model for estimating risk preferences differs from Antle's model in two major ways. First, the above model allows for market imperfections in the labour market. Second, the model explicitly incorporates the heterogeneous nature of labour inputs to production.

5.2.3 Estimation of Relationship between Prices Received and Paid by Households

The following regression will be estimated in order to model the link between prices paid and received by agricultural households:

$$lnP_S = a_0 + a(z) + blnP + e$$

where z is vector of household specific technology indicators which gives rise to household specific transaction costs, the coefficient a_0 measures the extent of market level fixed costs. The coefficient b measures the extent of market level variable transaction costs. This regression does not measure pricing efficiency, rather it estimates the correlation between prices received and paid by agricultural households and factors that may influence transaction costs.

Recall from Chapter 4, section 4.5:

$\ln P_{Si} = \ln(1+\tau_i)+\ln P$ for buyer households

$\ln P_{Si} = -\ln(1+\tau_i)+\ln P$ for seller households,

$i=1..n$ households, and $a(z_i)=\ln(1+\tau_i)$. A dummy variable signifying whether the household is a buyer or seller will be used to capture the difference in household specific transaction costs between household types. The above regression will be estimated for each of the major food staple crops.

5.2.4 Model for Estimating the Effect of Production Risk on Consumption

1. Consumption Demand

In order to account for censoring in food consumption shares observed across households the following model will be used:

$$\omega^* = \pi' X + \epsilon$$
$$Z^* = \pi' z + \xi$$

$$Z_i = 1 \; if \; \omega_i^* > 0$$
$$Z_i = 0 \; if \; \omega_i^* \leq 0$$

where,

ω	is a vector of unobserved latent demand shares for each household (i),
π	is a vector of coefficients
ϵ	is a vector of error terms
X	is a vector of exogeneous variable used in demand estimation
Z_i	is an element in the vector Z of binary variables which indicates censoring
z	is a vector of exogeneous variables which is used to predict the probability of censoring.

The conditional expectation of (ϵ) yields (see Greene, Goetz 1992)

$$E(\epsilon_i | \omega_i^* > 0) = -\sigma_\xi \left(\frac{\phi(\hat{Z})}{\Phi(\hat{Z})} \right)$$
$$E(\epsilon_i | \omega_i^* \leq 0) = \sigma_\xi \left(\frac{\phi(\hat{Z})}{1 - \Phi(\hat{Z})} \right)$$

where, the right hand side is the Inverse Mills ratio (MR) so that the estimated equation becomes

$$\omega = \pi' X + \sigma_{\xi} MR + e$$

The conditional mean of e = 0 but these error terms are heteroscedastic, as a result a weighting procedure is required to obtain efficient estimates.

Following Heien and Wessells, Lee's two step procedure will be used to account for censoring in the data. In the first stage the probability of the household consuming a given good is estimated along with the inverse Mills' ratio. In the second stage, the inverse Mills' ratio will be used to correct for any bias in the OLS estimates.

The model for the first stage of the estimation was specified as follows:

$$Z_{ih} = f(p_{1h}, \ldots, p_{6h}, m_h, d_{1h} \ldots, d_{sh})$$

where Z_{ih} is 1 if the hth household consumes the ith food item and 0 otherwise, p_{ih} are the prices of each food item, m_h is deflated household food expenditure, and d_{sh} is a vector of s household demographics. It is assumed that the probability of a household consuming a particular food item will depend on prices, food expenditure level and demographic variables. These variables should influence the probability of consuming a food item in the same manner as predicted by demand theory. In addition, it has been shown that variety is an increasing function of income (Jackson 1984). This effect is captured by including food expenditures in the equation (Heien and Wessells). Predicted values from the above equation is used in estimating the inverse Mills' ratio:

$MR_{ih} = \frac{\phi(\hat{Z})}{\Phi(\hat{Z})}$ if the household consumes the food item in question and $MR_{ih} = \frac{\phi(\hat{Z})}{[1-\Phi(\hat{Z})]}$ if the household does not consume the food item in question. ϕ and Φ are the probability density and cumulative probability functions respectively. The inverse Mills' ratio estimated from the above equations will be used as an instrument to estimate the system of demand.

In order to see how risk affects substitution in consumption among different food staples a demand system will be estimated as a function of the moments of production. The demand system estimation will be based on the Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980). The model will be specified as follows:

$$\omega_i = \alpha_i + \sum_j \gamma_{ij} lnP_j + \beta_i \ln(\frac{Y}{P^*}) + \theta_i lnFS + \delta_i s_M$$
$$+ \sigma^V{}_i var(R) + \sigma^S{}_i sk(R) + \delta_M MR + e,$$
$$where \quad lnP^* = \sum_k \omega_k lnP_k$$

where, Y is per capita food expenditure per household

ω_i is the share of food i out of total food expenditure

lnP_j is the logarithm of the price of food j,

$ln(Y/P^*)$ is the logarithm of the expenditure level discounted by a price index for food,

Var(R) and Sk(R) are respectively the second and third moments of revenue,

ln(FS) is the logarithm of family size (in adult equivalent units),

MR is the inverse Mills ratio and,

s_M is the measure of subsistence orientation out of production,

The subscript i,j refers to the food groups (food staples, vegetables and a composite of other foods). The variables VAR(R), SK(R), logarithm of land holdings by the household, ln(FS), and seasonal and regional dummies will be used in instrumenting

$\ln(Y'/P^*)$, and s_M. This will account for the possible endogeneity or simultanaeity between expenditure and subsistence orientation in the decision making process and also minimize the effects of measurement error. This model allows for the possibility of income and substitution effects of risk on consumption levels. The Marshallian price elasticities of demand may be estimated as:

own price $$\epsilon_{ii} = \frac{(\gamma_{ii} - \beta_i \omega_i)}{\omega_i} - 1$$

cross price $$\epsilon_{ii} = \frac{(\gamma_{ij} - \beta_i \omega_j)}{\omega_i}.$$

Expenditure elasticity of demand may be estimated as: $\eta_i = \frac{\beta_i}{\omega_i} + 1.$

Household size elasticity of demand: $\epsilon_{iFS} = \frac{(\theta_i - \beta_i)}{\omega_i}.$

Risk elasticity of demand: $\epsilon_{iV} = \sigma^{V_i}\left(\frac{\bar{var}(R)}{\bar{\omega}_i}\right).$

Downside risk elasticity of demand: $\epsilon_{iS} = \sigma^{S_i}\left(\frac{\bar{sk}(R)}{\bar{\omega}_i}\right).$

2. Calorie and Protein Demand

In order to see how risk affects the level of consumption the following regression will be estimated:

$$\ln(Cal_i') = a_0 + a_Y\ln(Y_i) + a_V Var_i(R) + a_d Sk_i(R) + a_s\ln(FS_i) + ds_{M_i} + seasonal\ dummies.$$

where, Cal_i is the logarithm of total calories consumed by the household. The coefficient on the logarithm of income (Y) and the family size (FS) variables yields the income and family size elasticity of calorie consumption respectively. A similar equation was estimated for protein consumed by the household. As in the food consumption equation, instruments of the variables ln(Y) and s_M were used in the regressions.

3. Consumption of Leisure

The model to be estimated is:

$$ls_i = \alpha_i + \sum_j \alpha_{ij} MVP_j + \beta_i \ln(\frac{V'}{P^*}) + \delta^F{}_i lnFS + \sum_j \delta^V{}_{ij} var(R) + \sum_j \delta^S{}_{ij} sk(R) + e_i$$

where $V' \equiv \sum_j MVP_j l_j$ *is the value of leisure for the household,*

$$ls_i = \frac{l_i \times MVP_i}{V'}.$$

$$V' = V + \sum_j a_{vj} var(R) + \sum_j a_{sj} sk(R) + \ln(land) + \ln(FS)$$

is the instrument for V *and* $ls_i = T_i - L^i{}_{OF} - L^i{}_F - L^i{}_{NW}$.

The subscripts i,j = male, female and MVP is the marginal value product of labour. The variable MVP approximates the true opportunity cost of family labour better than does the market wage rate. Estimating the consumption of leisure separately from food consumption assumes that the two are separable in household utility. The system focuses on the substitution between male/female labour in household consumption.

4. Labour Allocation

$$m_i = \frac{L_i}{T} = \alpha_0 + \alpha_{M_i} TM + \alpha_{F_i} TF + \sum_j \beta^{v}{}_{ij} cov(R, R_j) + \sum_j \beta^{s}{}_{ij} sk(R, R_j)$$
$$+ \beta^{vr}{}_i var(R) + \beta^{sk}{}_i sk(R) + \delta^{t}{}_i \tilde{T} + e_i$$

where, $\tilde{T}$ is proxy for household technology,
$T_M = \dfrac{MVP_M}{W_M}$ *and* $T_F = \dfrac{MVP_F}{W_F}$.

T_M and T_F represent the terms of trade of labour between farm and off-farm activities for males and females resepctively. The above equation will be estimated separately for males and females, where i=farm, off-farm, and non-income generating labour time.

5. Nutritional Status

Nutritional status is seen as an outcome of nutritional well being. The level of nutritional status of the children in the household will be used as a proxy for the level of nutritional well being of the household:

$$NS = \alpha_{NS} + \beta_{NS} Cal + \gamma_{NS} Cal^2 + \delta_{NS} HHC + \eta_{NS} G + \theta_f l_f + \nu l_M + \epsilon_{NS}$$

where, NS is nutritional status of children in the household, Cal is total calories consumed in the household, HHC is household characteristics such as land and asset holdings, HG refers to the genetics of the parents, and l_F and l_M are female and male leisure in the household. The endogeneity of calories available and household leisure is taken into account by using the predicted values from the calorie availability and consumption of leisure equations.

5.3 Data and Construction of Key Variables

The variables to be used in the estimation of the econometric model are derived from the data collected by IFPRI from Giciye commune in the northwestern part of Rwanda. The survey was collected from 200 households for the period 1985/86. The survey was conducted in 3 rounds: round 1, which was a recall survey for the year 1985 was conducted at the end of 1985; round 2 was conducted during the main growing season of 1986 and round 3 was conducted during the 1986 short season. The survey consisted of four modules:

A) Household demographics

B) Household consumption

C) Health of women and children and the Nutritional status of women, men and children

D) Household agricultural production and input use.

The sample of households selected was based on a location specific stratification (more details on the sample selection are provided in von Braun et.al. 1991).

The key variables that will be used in the estimations are: the moments of production (or the risk index, namely the mean, variance and skewness of production), food and leisure expenditure shares, index of prices received and paid at the household level for each food staple, wage rate and labour supply, and anthropometric measures of child nutritional status.

Derivation of Market Wages. It will be necessary to derive reservation wages based on market wages for those households in which no members work outside of the farm.

This will be done using Heckman's two step procedure. In the first stage exogeneous variables are used to determine the probability of participation in the work force. In the second stage, these probabilities are used to estimate a wage function. Labour supply will also be estimated using the same procedure. Predicted wages from the wage equation will be used in the estimation of risk attitudes.

Derivation of the Food and Leisure share Variables. The aggregation of foods into food groups is based on similarities in calorie and protein content, prices and use in consumption. The prices for these food groups will be aggregated with Stone's index. The weights to be used in the aggregation will be the market share of each crop for a given sector and round (Strauss 1986; Teklu and Johnson 1988). Foods will be aggregated into the following categories: potato category consisting of white potatoes, sweet potatoes, and manioc; the beans category consisting of peas and beans; the maize category consisting of maize, the sorghum category consisting of sorghum, wheat, and soya. Finally, fruits and vegetables will make up the fifth category followed by a sixth category consisting of all other foods (meats, fats and oils, dairy products, condiments). The equation to be used in estimating the price indices for each food group will be:

$$\ln P_j = \sum_{i=1}^{n} \omega_{ij} \ln q_i \quad and \quad \ln P^s_j = \sum_{i=1}^{n} \omega^s_{ij} \ln q^s_i ,$$

where,

n is the number of individual foods (i) in a given food group (j),

lnP and $\ln P^S$ are respectively the price index (for a given group of food staples) received and paid by agricultural households for their produce, q and q^s are respectively the price received and paid by agricultural households for a given food staple,

n is the number of food staples in a given group j,

ω_{ij}, ω^s_{ij} are respectively the weights assigned to each food in a given food group, the subscript i refers to a given food within food group j.

The above weights will be estimated as the share of calories of each food staple in a group out of the total calories of the group for food produced by the household; and the expenditure share of each food staple out of total expenditure of a group for foods consumed by the households. These indices will be estimated separately for each of the three rounds of the survey and four sectors (Rubare, Murambi, Birembo, and Gasasa). Calorie intake is based on 7-day recall and is adjusted for food eaten away from home and by non-family members.

Two measures for female leisure will be used in the nutritional status/anthropometric regressions. The first measure is based on the amount of labour days available in a household. This measure is estimated separately for males and females within a given household. The second measure of leisure is based on female time allocation data that was collected from a sub-sample of households (70 out of the total of 200). This measure of leisure is estimated from reported time allocated to leisure activities and does not include non-income generating work such as housework and time spent nurturing children or collecting wood. This measure is only available for female members in the sub-sample of 70 households.

Derivation of Child Nutritional Status. Anthropometric measures of child nutritional status will be used as indicators of household welfare. These measures have been estimated (by von Braun et. al. 1991) for children between the ages of 6 months and 6 years. The measures are respectively:

Height-for-age which represents a long-term indicator of past growth of the child which is a result of numerous factors beginning with birth weight and morbidity in addition to nutrient intake.

Weight-for-age represents a medium-term indicator and is related to the child's height and the extent of present undernourishment given a certain height.

Weight-for-height is a short-term indicator of child nutritional status (von Braun et al. 1991).

These scores are estimated as the actual measurement less the 50 percentile for the reference population over the standard deviation for the reference population. The reference population statistics for the present study was taken from the World Health Organization-U.S. National Center for Health Statistics (WHO-NCHS).

5.4 Conclusion

This chapter has developed an empirical model for the estimation of the effect of production risk on household food security. Specifically, it outlines the equations to be used in analyzing the way in which production risk impacts on: household consumption, labour supply, and labour allocation decisions. In addition, it briefly describes the data set and construction of important variables to be used in the estimations. The next chapter will summarize the results of the above estimations.

CHAPTER SIX
A MOMENT BASED ESTIMATION OF PRODUCTION RISK: ITS EFFECT ON HOUSEHOLD CONSUMPTION AND WELFARE

6.1 Introduction

This chapter uses the framework outlined in Chapter 4 and the empirical model of Chapter 5 to examine the effect of production risk on the substitution pattern between goods in the household consumption basket, and the level of household consumption and welfare. In terms of household consumption, this chapter will examine the effects of risk on food and leisure consumption. Risk effects consumption directly and indirectly through increased transaction costs which in turn lead to higher prices paid by households. Levels of consumption are effected through the income effect. Household welfare will be measured in terms of forgone income as a result of production risk and the nutritional status of children within the household.

The first section presents the results from the estimation of the moments of production (or the risk and downside risk indices). The second section will examine the effect of risk on the subsitution pattern of food consumption and female versus male leisure demand within the household. This section will also examine the role of risk in determining labour allocation decisions by the household. The third section will measure the welfare cost of risk. Finally, the last section will summarize the results of the analysis.

6.2 Derivation of the Moments of Production

The moments of production were estimated by using the moment based procedure outlined by Antle. Chapter 5 section 5.1 gives a detailed outline of the econometric procedure.

Table 6.1 shows summary statistics of the data used in the estimation of the moment function. The value of output was used in order to account for the correlation of prices and output. It was necessary to aggregate all crops into one output because inputs to production was not disaggregated by crop in the IFPRI survey and also because there is a high level of inter-cropping in the area. Output consisted of an aggregation of the major food staples. Staple foods are defined as maize, beans, peas, potatoes, sweet potatoes and Gishwati potatoes (which refers to potato production with modern inputs) and sorghum. All expenditures are in FRw. Expenditures for tools in rounds 2 and 3 were discounted with a 5% discount rate. The price index used in discounting prices to the first half of 1985 was defined as follows: the sum over all households in the sample of the value share of each crop grown out of the total value of food staples grown multiplied by the unit price of the crop recieved by each household. All expenditures and income values in the analysis are relative to the price of potato for the lowest expenditure group (which was estimated as 6.14 FRw).

Table 6.2 contains results for the moment function with the assumption that labour is homogeneous. The results are derived from Generalized Least Squares (GLS) estimation of the moments. The sample mean of the third distribution shows that the distribution of total reveune is positively skewed. The third moment was standardized by dividing it by the cube of the square root of the second moment (Roumasset 1976). The Wald test for the significance of the regression shows that all three regressions are significant.

The second moment of production measures the squared deviations about the mean. This is a measure of the degree of risk in the area. The third moment measures the cubed deviations about the mean. It is a measure of the degree of downside risk in the area. According to Table 6.2 production is positively skewed in the area. This is a reflection of the adverse production situation faced by producers in the area. Positive skewness means that risk is transfered from below the mean of the distribution to above the mean or that the mass of the distribution is centred at a low value (Antle 1990). Therefore, the probability of a low level of production is high but the risk associated with it will be lower compared to production levels above the mean. The results from the estimation of the moment of production suggest that the pattern of input use is such that some minimum level of production is ensured. However, this minimum level of production does not necessarily ensure that consumption requirements are met.

The estimated elasticities are of the same order as Antle (1983, 1987, 1988). The elasticity of the first moment with respect to all inputs are positive. Results of the second moment suggest that all inputs except land and animal capital are risk decreasing. This may be a reflection of the variation of yields across agroclimatic regions. Labour, land and animal capital cause positive skewness of revenue. Therefore, labour contributes positively to average production, is risk reducing and contributes to the protection against downside risk. Land on the other hand contributes positively to average production, is risk increasing but provides protection against downside risk. These results reflect the important role of these inputs as factors of production in the study area. This also suggests that labour supply of the household is a key variable in handling revenue risk. In order to examine this, moment functions for revenue were re-estimated with labour disaggregated by family versus hired labour, and by gender of family labour. All other inputs were kept fixed. This was implemented by specifying a quadratic expansion of the different kinds of labour and a linear expansion of all other (fixed) inputs in the moment functions. The results for the estimated elasticities are shown in Table 6.3. Female labour appears to be risk increasing whereas all other kinds of labour are risk reducing. All labour contribute to the protection against downside risk.

This section has summarized the results from the estimation of the moments of production. The estimation is based on the assumption that the moments of production is household specific and will be a function of the pattern of input use for a specific household. Seasonality in production (along with any weather shocks) also means that production will vary in the same way over time for households in the same region. The variance and skewness will be used as risk and downside risk indices in the remaining sections to examine the effect on household consumption and welfare.

Table 6.1: Definition and Corresponding Statistics of Variables used in Estimating the Moments of Production

Variable Name and Definition		Mean	Standard Deviation
Value of Output	Value of staple food crops harvested + production value of livestock	2340.92	4517.29
Other Inputs	Expenditure on chemicals and pesticides	36.29	135.37
Seed	Expenditure on seeds	76.39	261.3
Hired Labour	Hired labour days allocated to staple crop production	15.06	21.95
Child Labour	Child labour days allocated to staple crop production * .2	1.99	4.05
Male Labour	Male labour days allocated to staple crop production	8.18	12.50
Female Labour	Female labour days allocated to staple crop production	24.37	20.17
Total Labour	Hired labour + Child labour + Male labour + Female labour	50.60	42.66
Land	Farm size in hectares	.74	.66
Tools	Value of farm equipment	187.54	230.52
Head's Age	Age of head of household	42.37	14.10
Livestock	Expenditures on all livestock inputs	106.63	529.73
D2 and D3	Dummies rounds 2 and 3	.33	.47

Table 6.2: Estimates of Elasticities of inputs with respect to Moments of Production at Sample Means

	Moments of Production		
Inputs to Production	First (Mean)	Second (Variance)	Third (Skewness)
Chemical Inputs	0.003647 (0.255)	-0.07665 (0.2362)	-0.3746 (2.13)
Seed	0.003789 (.089)	-0.52377 (0.358)	-0.81068 (3.696)
Labour	0.2946 (0.0459)	-0.12153 (0.3749)	4.926 (2.888)
Land	0.75696 (0.085)	6.206 (0.91)	54.315 (5.769)
Tools	0.04215 (.0303)	-4.594 (0.3056)	-5.758 (2.794)
Animal Inputs	0.003635 (.00426)	46 (.196)	217.48 (.249)
Sample Means (FRw)	2340.92	1540.47	1712.48
$CHI^2(22)$	4786	123.75	104.33

Note: Standard errors are in parenthesis.

Table 6.3: Estimates of Elasticities of Labour Inputs with respect to Moments of Production at Sample Means

	Moments of Production		
Labour Inputs to Production	First (Mean)	Second (Variance)	Third (Skewness)
Male Labour	.147	-.0492	12.44
Female Labour	.322	.419	2.13
Child Labour	.293	-.324	7.69
Hired Labour	.519	-.288	26.29

NOTE: All other variables except disaggregated labour are specified as fixed inputs to production.

6.3 Effect of Risk on Household Consumption

This section estimates the effect of production risk on household consumption of food and leisure. Production risk effects household consumption directly through its effect on the subsitution pattern between goods in consumption. It effects consumption indirectly through its impact on income and prices paid by agricultural households. The effect of risk on prices paid by households is achieved through its effect on transaction costs. Production risk may increase the wedge between prices paid and received by agricultural households. In order to model the transaction cost effect of risk a simple equation which links prices received and paid by agricultural households was estimated. The effect of risk on food and leisure substitution patterns and the corresponding income effects was estimated with elasticities derived from demand equations. The results are summarized below.

6.3.1 Estimating the Link Between Household Level Prices Received and Paid for Food Staples

A sectoral level price index was derived and assigned to each household within a given sector for a given round. This was then assigned to the respective household in each sector and survey round. The risk and downside risk indices were estimated using the equation in Chapter 5 section 5.1.3. Table 6.4 provides the results of the link between household specific supply and demand prices. The dependent variable is the log of prices paid by agricultural households in Giciye and the independent variables are the log of prices received and other variables which are proxies for sectoral and household specific factors which may influence transaction costs. Prices of food staples in Table

6.4 are relative to the first period's prices received. The wealth variable captures household technology and quality effects which may influence prices paid by households. For example, wealthier households may be able to purchase foods in bulk and therefore pay lower prices relative to more resource constrained poorer households. On the other hand, wealthier households may pay relatively higher prices and are able to incur greater search costs in order to purchase foods of good or higher quality. The significant and positive coefficient on potato and sorghum for this variable suggest that the latter situation prevails. Wealthier households predominantly purchase white potatoes which are slightly more expensive than sweet potatoes. These households also purchase higher quality sorghum (as opposed to lower quality sorghum which is used in sorghum beer production mainly by the poorer households). Distance from water source is a proxy for the degree of remoteness of the household from highly settled areas or markets. This variable is positively related to prices paid by households for potatoes. However, it is negatively related to prices paid for maize and sorghum. Maize is not a commercial crop in the area. The negative sign on this variable in the maize equation may be a reflection of the fact that households will consume more from own production when prices are high in the market. More isolated households will therefore consume more from own production in order to capture the lower price. Sorghum is an input to the production of sorghum beer. The negative sign here may reflect the fact that households which are relatively more isolated are likely to be poorer and therefore rely more on sorghum beer production in order to supplement income. These households therefore purchase the lower quality sorghum whereas the wealthier households purchase the high quality sorghum. The number of children in the household relative to adults does not appear to have a significant effect on transaction costs.

The risk index is insignificant in the potato, maize and sorghum regressions, but is significant and positive in the beans regression. The interaction of the dummy for buyer households with the risk index is positive and significant for the potato equation and insignificant for the other equations. This coefficient is negative only for the beans equation. These results support the hypothesis that seller households are better able to manage production risk and may even take advantage of this risk when prices and quantities are highly negatively correlated. These households accomplish this by selling more when prices are high and consuming more from own production when prices are low (de Janvry and Sadoulet 1993).

In the case of the downside risk index, an increase in the downside risk index means the probability of a lower level of production is high. This reflects adverse production decisions in the area. The sign of the coefficient on the downside risk index is significant and negative for potato and maize and signficant and positive for sorghum. The explanation for this result arises from the tendency of an increase in adverse production conditions to lead to more consumption out of home production. As a result, the imputed price paid by the households for the crop which it also produces is lower than the market price. The potato price index includes sweet potatoes which is a subsistence crop and maize is also a subsistent crop. However, sorghum beer production is a commercial venture. Since most households grow more potatoes and maize relative to sorghum, there will be a tendency to rely on the market more for sorghum which is used as an input into sorghum beer production. Therefore, adverse production conditions will lead to higher prices paid for sorghum by those households which produce sorghum beer. The coefficient on the interaction term between the buyer household dummy and the downside risk index is negative for potatoes, maize and sorghum and positive for beans. This coefficient is significant only in the potato equation. This signifies that lower downside risk benefits buyer households more (in terms of a lower price paid for potatoes) than seller households.

This simple regression identifies production risk as a significant component of the transaction costs faced by Rwandan households. It also shows that production risk translates into higher prices paid for food staples by buyer households than by seller households. This equation will be used in Chapter 6 in performing a micro-simulation of pricing policies which have been implemented by the Rwandan government in the past.

Table 6.4: The Relationship between Household Level Supply and Demand Prices for Food Staples

	Results of Household Level Transaction cost Regressions for the staple Food Groups				Statistical Summary of Regression Variables	
Variable	**Potato**	**Beans**	**Maize**	**Sorghum**	**Mean**	**Standard Deviation**
Intercept	.314 (2.932)	.0662 (1.383)	.4854 (6.1)	.7359 (9.68)		
Wealth	.0176 (1.701)	-.00307 (-.827)	-.0105 (.96)	.0123 (1.58)	9.15	.57
Distance from water source (minutes)	.00047 (1.78)	.00008 (.9)	-.00102 (-5.49)	-.0009 (-4.76)	28.93	22.85
Dummy for Buyer Households	.00345 (.287)	-.00453 (-1.1)	.00354 (.427)	-.0261 (-.289)	.54	.5
Dependency Ratio	.01008 (.380)	-.00389 (-.417)	-.0242 (-1.3)	-.0206 (-1.04)	.36	.22
Risk Index	-.00145 (-.359)	.002989 (2.102)	-.00234 (-.843)	-.0009 (-.284)	1.62	2.16
Risk Index*Dummy for Buyer Household	.0183 (2.2)	-.0056 (-1.87)	.0062 (1.06)	.0070 (1.08)		
Downside Risk Index	-.00348 (-6.94)	-.00009 (-.518)	-.00119 (-3.43)	.0012 (3.01)	3.26	17.55
Downside Risk*Dummy for Buyer Household	-.0029 (-2.78)	.0003 (.827)	-.0009 (-1.18)	-.0011 (-1.33)		
Log(Price received for Potato)	.6354 (11.61)				1.80	.24
Log(Price received for Beans)		1.004 (28.83)			3.37	.22
Log(Price recieved for Maize)			.6859 (16.52)		2.73	.30
Log(Price received for Sorghum)				.581 (27.87)	4.04	.13
Adjusted R-Squared	.291	.635	.413	.692		
F-Statistic	31.38	125.93	53.09	167.22		
Degrees of Freedom	517	503	519	519		
Mean of Log(Price paid)	2.06	3.52	2.82	3.95		
Standard Deviation of Log(price paid)	.14	.17	.10	.40		

6.3.2 Estimating the Effect on Household Consumption

In this sub-section, consumption demand is divided into food and leisure demand. This sub-section also examines the effect of risk on the labour allocation decisions of males and females.

Food Demand. This section summarizes the results of the income, price and risk elasticities of demand for the major food staples in Rwanda. This is particularly important for white potatoes which is the major commercial crop and a food staple in the area. Sorghum is also an important commercial crop in the area in that it is used in the production of sorghum beer for sale by the household. Table 6.6 summarizes the demand elasticities for risk, income and compensated prices by household type. The elasticity estimates are based on a systems estimation of the demand groups (see Appendix, Table 6.15). The price elasticities are of the same order as those estimated by other studies for Rwanda (Minot). Buyer and seller households both appear to substitute away from the more risky commercial crop (potatoes) and toward the less risky crops (sorghum and beans). Both households appear to rely more on the purchase of sorghum for sorghum beer production with an increase in the risk index (von Braun et.al. 1991; Matthess-Guerrero 1991). In the case of buyer households, as the risk associated with a low level of production falls, these households substitute toward the more commercial and risky crop (potatoes) and away from the other staples. Whereas, seller households consume less of the commercial crop (potatoes) and more of the less risky crops. Downside risk has a stronger influence on the consumption of potatoes for buyer households. An increase in the downside risk index is a reflection of adverse production patterns (Antle). Therefore, Table 6.6 reflects the fact that an increase in the downside risk index of production will cause seller households to consume less from production and sell more as prices are likely to be higher. Whereas, buyer households are worse off in that there is less availability of the staple on the market. As a result, these households substitute toward relatively less expensive crops (potatoes). The pattern of the income elasticity of demand for these foods shows that for the most important staples this elasticity declines as income increases.

Direct estimation of the expenditure and risk elasticities using calorie intake yielded the results in Table 6.7 (see Appendix). Risk has a negative effect on calorie consumption although it is not strongly significant. Downside risk also has a negative but strongly significant effect on calorie intake. These results show that risk has a negative effect on the level of consumption. These effects are however not significantly different for buyer versus seller households.

Table 6.5: Summary of Income Compensated Price Elasticities

Food Group	Compensated elasticities with respect to Price of					
	Potatoes	Beans	Maize	Sorghum	Fruits and Vegetables	Other Foods
Potatoes	-1.16	.1997	.0799	-.1731	.2128	.1212
Beans	-.5279	-.2866	-.2122	-.1161	-.3017	.2299
Maize	-.7531	.1474	-1.18	-.0769	-.1228	.5128
Sorghum	-.2095	.5841	.1604	-.908	.4483	.1225
Fruits and Vegetables	.3305	-.2319	.4533	.2164	-1.17	.2478
Other Foods	.1383	.1999	.1917	-.0497	.2059	-.9504

Table 6.6: Income and Risk Index Elasticities by Household type

	Food Group					
Food Expenditure Elasticities by Expenditure Tercile	Potatoes	Beans	Maize	Sorghum	Fruits and Vegetables	Other Foods
Lowest Tercile	.8874	1.40	2.30	1.95	.537	-.0977
Middle Tercile	.8793	1.39	2.30	1.52	.542	-.0059
Top Tercile	.8574	1.09	2.27	1.70	.514	.0128
Mean	.8747	1.29	2.29	1.72	.531	-.0030
Risk Elasticities by Household Type						
Risk						
Seller Household	-.0624	.0618	-.0495	.4364	.0616	-.0435
Buyer Household	-.0806	.1191	.0396	.3010	.0493	.2795
Downside Risk						
Seller Household	-.0027	.0154	.0212	-.1272	.0059	.0004
Buyer Household	.0082	-.0265	-.0176	-.1245	.0189	-.0367

Table 6.7 Expenditure and Risk Elasticities with respect to Nutrient Intake

	Calories	Protein
Expenditure Elasticties		
Tercile 1	.670	.667
Tercile 2	.601	.595
Tercile 3	.565	.564
Risk Elasticties		
Seller Household	-.0487	-.0211
Buyer Household	-.0503	-.0016
Downside Risk Elasticities		
Seller Household	-.0288	-.031
Buyer Household	-.037	-.046
Mean	2611.59	120.77
Standard Deviation	1102.72	64.19

Leisure Demand. Table 6.8 summarizes the elasticities for leisure demand with female leisure defined in terms of hours or labour-days worked. Elasticity for female labour supply suggests that the labour supply schedule is upward sloping. Male and female labour appear to be complements, and leisure is a normal good with a high income elasticity of demand. Risk does not significantly affect leisure demand by females. However, downside risk does significantly affect leisure demand by both buyer and seller households. Elasticities were estimated from the coefficients of a demand system. As with food demand, the system was estimated using the seemingly unrelated regressions (SUR) package of SAS. Unlike the food demand system, no restrictions were placed on the coefficients.

The risk index has different effects on different household types. In seller households, an increase in the risk index causes males to work more labour-days and females less labour-days. An explanation of this may be that seller households are more commercially oriented and men supply more labour to the commercial crop (potato). As a result, an increase in the risk index causes men to work harder. Whereas, buyer households tend to be more subsistence oriented and female labour provides the greater proportion of labour used in subsistence production. As a result, an increase in the risk index causes females in these households to work more labour-days while males work relatively fewer labour days. The hours equation for females was estimated (from the sub-sample of 70 households). Non-income generating work was not included as part of the definition of female leisure. The results for the elasticities yield the same signs as for the female equation with leisure measured in labour-days for all variables except for the downside risk variable. In this case the sign is the same as for males. An increase in the downside risk index causes females in seller households to work harder while buyer households work less. This may be a reflection of the relatively more limited household resources (such as land) available to the buyer households for income generating purposes.

Table 6.8: Summary of Leisure Demand Elasticities

Elasticities for Leisure Demand with respect to Wage and Risk Indices			
Leisure Demand	**Female (Hours)***	**Female (Labour Days)**	**Male (Labour Days)**
Female	-1.29	-.8290	-.2260
Male	-.8800	-.4010	-.4690
Adult Equivalent Units	-.8940	-.1690	.2270
Value of Leisure (opportunity cost)	2.89	1.28	.6290
Risk Elasticities by Household Type			
Seller	.0308	.0016	-.0022
Buyer	-.0450	-.0019	.0025
Downside Risk			
Seller	-.0528	.0027	-.0036
Buyer	.0120	-.0013	.0017

Note: *The definition of leisure for this equation does not include non-income generating work such as wood gathering, fetching water, and other housework.

The Impact of Risk on the Allocation of labour between farm and non-farm activities. This section addresses the question of whether risk is a major determinant in the allocation of labour between farm and non-farm activities. In the previous section risk did not significantly determine the level of leisure demand. In the current section risk appears to play a larger part in the allocation of female labour between farm and non-farm activities than it does in the allocation of male labour. This relationship is summarized in Table 6.9. The dependent variable is the share of female and male labour allocated to off-farm activities out of total labour supply measured in labour-days. The terms of trade between farm and off-farm productivity is defined as the natural logarithm of the ratio of the marginal value product of family labour to the market wage rate.

In the allocation of male labour only the terms of trade for female labour is significant and negative. A relative increase in the productivity of female labour on the farm increases the allocation of male labour off-farm. However, for female labour allocation, an increase in the productivity of female labour on the farm leads to more female labour allocated on the farm. The risk index is siginficant in the female equation and causes an increase in the proportion of labour allocated off-farm by females and an increase in the proportion of labour allocated on-farm by males. This is explained by the results of Table 6.3 which shows that although female labour is more productive than male labour, it is risk increasing while male labour is risk decreasing. The household therefore, must rely on male off-farm labour supply to offset the effects of production risk. There is no significant difference in the effect of risk on the labour allocation of females in buyer versus non-buyer households. However, with regard to downside risk, there is a significant difference between the labour allocation of females in both household types. Females in buyer households allocate more labour on-farm with a decrease in the level of downside risk to production.

Table 6.9: Determinants of the Allocation of Labour between Farm and Off-Farm Activities

	Parameter Estimates			
Variables	Share of Female Off-Farm Labour	T-Stat	Share of Male Off-Farm Labour	T-Stat
Intercept	.0383	0.06	-.193	-.359
Terms of Trade for Female Labour■	.244*	2.57	- .116*	-2.645
Terms of Trade for Male Labour■	.0946	1.03	-.046	-.806
Risk Index	- .1015*	-1.7	.011	.257
Downside Risk Index	.0079	0.39	.0043	.328
Subsistence orientation in Labour Use	4.17*	3.72	.746	1.12
Subsistence orientation in production	- .0006	-.203	.00015	.0643
Log (land)	- .0142	-.1587	.0233	.3141
Log (Adult Equivalent Units)	- .294*	-1.99	- .0237	-.238
Buyer Household Dummy*Risk Index	- .318	-1.62	- .0836	-1.098
Buyer Household Dummy * Downside Risk Index	.0905*	2.01	.009	.434
Sector 2 Dummy	- .185	-1.22	-.058	-.454
Sector 3 Dummy	-1.51*	-3.76	- .0059	-.024
Sector 4 Dummy	- .710*	-3.16	- .0082	-.065
Relative Risk Effect•	.0067	.402	- .00024	-.203
Relative Downside Risk Effect•	-.0169	-1.14	.002	1.158
Log-Likelihood	-22.474		-135.478	

NOTE: Dependent variable is the share of male/female labour-days worked off-farm as a proportion of total labour-days worked (off-farm and on-farm respectively for each gender). Sectors refer to the local government areas which were surveyed--see Figure 2.1.

* Signifies that the coefficient estimates are significant at the 10% level or less.

■ Is defined as the ratio of the returns to labour on farm to the market wage rate.

• Is defined as the ratio of the marginal effects of male and female labour on the variance and skewness of production.

6.4 The Impact of Risk on Household Welfare

In order to explore the possibility that labour supply may be rationed, and calculate risk attitude coefficients, the equation specified in section 5.1.2 was estimated. This equation is based on the first order condition for labour. At the optimum, labour should be allocated so that the marginal value product of labour on farm is equal to the wage rate. If there is rationing in the market, then the marginal value product and the wage rate will not be equal. The regressions were estimated assuming labour was homogeneous and then re-estimated with labour disaggregated according to whether it was male, female family labour or hired labour. The wage rate used in this regression (and in the leisure demand and labour allocation regressions) were estimated using a Heckman two-step procedure. The parameter estimates used in predicting wages for dividuals that did not work off-farm are summarized in Tables 6.17 and 6.18.

The results of these regressions are summarized in Tables 6.14 in Appendix 6.1. The disaggregated regressions were also estimated using two stage least squares (2SLS) and a system method three stage least squares (3SLS) in order to account for any correlation in the error terms across the three first order conditions for the various types of labour. This system estimation captures the possible effects of risk sharing between males and females within the household. If there is risk sharing between males and females, then the error term between the labour first order conditions should be correlated.

The regression estimated with labour defined as a homogeneous input suggests that there is rationing of labour in the market. However, the wage rate and the productivity of labour on the farm are positively correlated. The coefficient estimates used in estimating risk attitudes are significant for risk and downside risk. The significant coefficients on the seasonal dummies suggests that seasonality is important in determining the allocation of labour.

The next set of regressions in Table 6.15 are estimated with labour disaggregated by gender and by family and hired labour. The methods of 2SLS and 3SLS both support the previous results of rationing in the labour market. In the 2SLS regression, only hired labour shows a siginificant correlation with the market wage rate. The coefficients on the seasonal dummies suggests that seasonality is important in the allocation of labour for males and females but not so much for the use of hired labour. The coefficients used in estimating risk coefficients is slightly significant at the 15% level. In the 3SLS regression, both female and hired labour show a significant correlation with the market wage rate. However, seasonality appears to be only significant in determining male labour allocation. The coefficients used in estimating risk attitudes is not significant in the equations.

The equations described in Chapter 5 (section 5.1.2) for risk attitude estimation was implemented by assuming a price elasticity of demand equal to -.62 (from the estimates in Table 6.5) for beans which is an important food staple predominantly used by the poor as a source of protein (Scott 1988 and Loveridge 1988). The income elasticity of demand is taken as .67 (from Table 6.7). The estimates of β and s_M are taken as .425 and .69 respectively with a mean agricultural income of 13,176.16 Frw (von Braun et.al.).

Table 6.10: Summary of Risk Attitude Estimation

Risk Coefficients	Homogeneous Labour (2SLS)	Heterogeneous Labour (2SLS)	Heterogeneous Labour (3SLS)
Arrow Pratt Measure of Relative Risk Aversion	4.58 (5.51)	4.14 (1.443)	.67 (1.261)
Measure of Relative Downsdie Risk Aversion	1.71 (11.31)	.324 (.710)	-.053 (-.260)
Risk Premium Measure as percentage of agricultural income	23.1	23.3	4.03

NOTE: T-statistics are in parentheses.

The above table summarizes the risk attitude coefficients and risk premium esitmated under the various methodologies and level of labour disaggregation. The risk premium estimated with 2SLS is roughly the same whether labour is disaggregated or not. However, the risk premium estimated in order to account for any possible correlation of the error term on the first order condition across the different labour types (3SLS) is significantly lower. This result illustrates the importance of family labour supply (particularly male labour supply) as a means of risk sharing and thereby managing risk faced by these households.

Risk affects nutritional status through male and female household leisure and through its effect on household calorie consumption. As can be seen from Tables 6.11 and 6.12, calorie consumption has a positive effect on the nutritional status of children in the household. Female leisure has a more significant and negative effect on long run measures of the nutritional status of the child than does male leisure.

Past studies that have examined the effect of cash cropping on child nutritional status argue that increased participation by the household in the cash cropping scheme translates to a decline in time spent nurturing children and therefore, a decline in child nutritional status. However, as Tables 6.11 and 6.12 show it is not simply the participation of the household or mother but the demand on the mother's time. The measure of female leisure which includes time allocated to non-income generating work (Table 6.11) has a negative effect on child nutritional status. Whereas, the measure of female leisure (Table 6.12) based solely on pure leisure time (not including time spent on non-income generating work) has a positive effect on child nutritional status.

From the previous section it was concluded that risk causes a decline in calories. The effect of risk through calories consumption will have adverse consequences for child nutritional status. However, the effect of risk on leisure demand of males and females is more ambiguous. It depends on the type of household and whether non-income generating income is included in the definition of leisure. The total effect of risk on nutritional status of children may be ambiguous. Given the importance of calorie consumption in determining nutritional status, it is likely to be negative especially for the buyer household.

6.5 Conclusion

This chapter estimated the effect of production risk on household consumption and welfare. In order to accomplish this, risk indices were estimated which reflected the degree of variation of production about the mean in the study area along with the probability of low production levels occuring. When these indices were incorporated into a demand function interesting results were found. The estimates of risk and downside risk reflect the adverse production conditions in the study area. The risk index elasticities with respect to the inputs to production found labour to be a key variable in managing production risk. This risk was found to be a significant component of transaction costs and had an effect on consumption. It was found that risk causes seller households to substitute toward less risky crops in consumption and sell more of the risky crop in order to capture the higher returns. Buyer households, substituted toward the more commerical crop, potato, which is relatively cheaper as other crops become relatively scarcer and more expensive with decreased downside risk (or increased positive skewness of production). Risk causes a decrease in the level of consumption for all household types. The differences in this decline across household types are not significant.

In terms of leisure demand (or labour supply) risk causes an increase in labour supply for females in buyer households which are more subsistence oriented while males in these households work less. Males in more commercially oriented seller households work harder with increased risk while females work less. Risk also causes a positive loss in welfare for these households. The loss is lower if the possibility of risk sharing between males and females within the household is taken into account. The next chapter will use the results of this chapter in implementing a micro-simulation model to examine the possible effects of floor price policies on household food consumption in Rwanda.

Table 6.11: Effect of Production Risk on Child Nutritional Status (Leisure measured in Labour-Days)

	Height for Age (HAZ)		Weight for Age (WAZ)		Weight for Height (WHZ)		Variable Statistics	
Variable	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.	Mean	Std. Dev.
Calories	.0001	2.741	.00007	1.918	.0003	2.312	2655.3	1086
Calories Squared					-.00000004	2.190	8224643	6628221
Sick Days			-.0176	-3.244	-.0212	-4.878	3.81	6.96
Clean Toilet	.3368	3.362	.0911	1.184			.62	.49
Rank	-.1228	-2.54	-.1719	-4.635	-.1072	-3.581	2.90	1.68
Sex	.3564	3.66	.3159	4.227	.1093	1.844	.54	.50
Age	-.0082	-3.17	-.00369	-1.844	.0026	1.608	43.12	22.03
Height of Mother	.0295	3.476	.0168	2.578	.0059	1.127	156.82	5.43
Height of Father	.0357	3.327	.0147	1.782			165.87	4.49
Female leisure/hh	-.0332	-2.09	-.0211	-1.736	-.0022	-.229	454.65	103.23
Male leisure/hh	.0002	.030	-.0033	-.598	-.0037	-.845	470.80	51.27
Gishwati	.3432	3.249	.29	3.578	.0614	.954	.48	.50
Buyer Household Dummy	-.1792	-1.83	.0059	.079	.1649	2.781	.47	.50
Intercept	-9.972	-3.96	-3.954	-2.046	-.5342	-.529		
R Squared	.138		.108		.100			
F Statistic	10.42		7.553		7.59			

Table 6.12: Effect of Production Risk on Child Nutritional Status (leisure measured in Hours)

	Height for Age (HAZ)		Weight for Age (WAZ)		Weight for Height (WHZ)		Variable Statistics	
Variable	Coefficient	T-Stat.	Coefficient	T-Stat.	Coefficient	T-Stat.	Mean	Standard Deviation
Calories	.0002	2.123	.00004	.634	.0004	2.494	2655.3	1085.7
Calories Squared					-00000008	-2.78	8224643.9	6628221
Sick Days			-.0168	-1.93	-.0244	-3.60	3.81	6.96
Clean Toilet	.2376	1.425	.1299	.941			.62	.49
Rank	.0976	1.605	-.0698	-1.38	-.0867	-2.06	2.9	1.68
Sex	.4564	3.11	.2645	2.178	.0436	.431	.54	.50
Age	-.0014	-.369	.0008	.258	.0036	1.370	43.12	22.03
Height of Mother	.0404	2.942	.0268	2.362	.0111	1.175	156.82	5.43
Height of Father	.0599	3.629	.018	1.327			165.87	4.49
Female leisure/hh	.2918	2.158	.3931	3.465	.2194	2.32	12.46	.76
Buyer Household Dummy	-.0196	-.624	.123	1.006	.3311	3.298	.47	.50
Gishwati Dummy	.1049	.574	.2367	1.565	.1885	1.682	.48	.50
Intercept	-22.86	-5.66	-13.22	-3.95	-4.745	-2.48		
R Squared	.140		.101		.16			
F Statistic	5.064		3.54		5.75			

Appendix 6.1

Table 6.13: Summary of the Food Demand System

Independent Variables	Dependent Variables (Share of Food Group out of Total Food Expenditure)					
	Potato share	Beans share	Maize share	Sorghum share	Fruits and Vegetables share	Other Foods share
Log of Price of						
Potato	-.00816 (-.105)	-.01484 (-.261)	.0352 (.964)	-.062** (-2.5)	.0729** (3.25)	-.0235* (-1.89)
Beans	-.0148 (-.261)	.1032** (1.97)	-.044 (-1.52)	.0144 (.768)	-.0688** (-4.71)	.01049 (1.33)
Maize	.0352 (.964)	-.0445 (-1.52)	-.0123 (-.372)	.0165 (1.17)	-.0133 (-1.42)	.01846** (3.51)
Sorghum	-.0616** (-2.5)	.0144 (.768)	.0165 (1.17)	.0119	.0355** (2.68)	-.0158** (-2.13)
Fruits and Vegetables	.0729** (3.25)	-.0688** (-4.71)	-.0133 (-1.42)	.0355** (2.68)	-.0431** (-2.03)	.01669* (1.74)
Other Foods	-.0235* (-1.89)	.0105 (1.33)	.0185** (3.51)	-.0158** (-2.13)	.01669* (1.74)	-.0063 (-.627)
Coefficient of Variation in Production	-.01702* (-1.9)	.00769 (1.41)	-.0028 (-.822)	.00994	.00467 (.611)	-.00248 (-.359)
Coefficient of Skewness in Production	-.000363 (-.344)	.00095 (1.46)	.000597 (1.48)	-.00144	.000249 (.275)	.00001122 (.014)
Subsistence Degree	.0719** (2.32)	-.0458** (-2.22)	.00284 (.225)	-.03702	-.0149 (-.599)	.02298 (1.04)
Log of Food Expenditure	-.0637 (-1.02)	.0815* (1.73)	.137** (4.02)	.0262	-.06658* (-1.67)	-.09112** (-2.78)
Log of Adult Equivalent units	-.00454 (-.14)	.0192 (.887)	.0453** (3.42)	.01497	-.0258 (-1.02)	-.04913** (-2.22)
Mills ratio	.0809** (2.22)	.0037 (.394)	.0173** (3.59)	-.0144	-.01922* (-1.70)	.0217** (3.95)
Log of Food Expenditure*Dummy for expenditure tercile 1	.01339** (2.38)	.0000253 (.007)	.00397* (1.81)	.00919	.00204 (.416)	-.01024** (-2.37)
Log of Food Expenditure*Dummy for expenditure tercile 2	.0088* (1.71)	-.00372 (-1.18)	-.0002 (-.103)	-.00692	.00377 (.855)	-.00173 (-.433)
Coefficient of Variation in Production*Dummy for buyer household	-.00495 (-.471)	.00712 (1.1)	.00504 (1.26)	-.0168	-.0088 (-.965)	.0184** (2.23)
Coefficient of Skewness in Production*Dummy for buyer household	.00147 (.915)	-.00259** (-2.63)	-.0011* (-1.79)	.00267	.000593 (.428)	-.00105 (-.838)
Intercept	.5066 (4.34)	.04456 (.573)	-.0579 (-1.17)	-.02236	.2715** (3.06)	.2576** (3.32)

Independent Variables	Dependent Variables (Share of Food Group out of Total Food Expenditure)					
	Potato share	Beans share	Maize share	Sorghum share	Fruits and Vegetables share	Other Foods share
Adjusted R-squared	.582	.883	.949		.77	.769
F-Statistic	49	261.2	642		116.93	116.77
Mean of shares	.4896	.222	.1195	.0892	.1634	.1532

Note: ** Significant at the 5% level or less.
* Siginficant at the 10% level or less.

Table 6.14: Estimation of Risk Attitudes Based on Labour First Order Condition with Aggregated Labour

	Coefficient		Statistical Summary	
Variables	Estimate	T-Stat	Mean	Standard Deviation
Intercept	-75.72	-2.94		
Wage	.285	1.69	117.49	40.74
Marginal Effect of Labour on Risk	-1.21	-5.51	-20.259	19.36
Marginal Effect of Labour on Downside Risk	.0097	11.305	9206.45	4199.19
Dummy Round 2	10.07	1.11		
Dummy Round 3	49.3	3.2		
Adjusted R-Squared	.22			
F-Statistic	32.78			
Degrees of Freedom	571			

Note: Hired wage is not disaggregated into male/female types and male/female wage refers to family wages.

Table 6.15 : Estimation of Risk Attitudes Based on Labour First Order Condition with Disaggregated Labour

	Results by Estimation Method							
	Two Stage Least Squares			Three Stage Least Squares			Statistical Summary	
Variables	Female	Male	Hired	Female	Male	Hired	Mean	Standard Deviation
Intercept	24.063 (1.01)	-10.51 (-.65)	52.39 (4.788)	30.58 (2.83)	-21.32 (-1.67)	43.47 (6.12)		
D2	13.105 (1.56)	23.21 (2.812)	.655 (.175)	8.7 (1.44)	26.54 (2.87)	-.311 (-.098)	.33	.47
D3	9.59 (.607)	25.99 (2.152)	2.587 (.417)	-.99 (-.117)	42.35 (3.88)	3.92 (.871)	.33	.47
Female Wage	-.13 (-.74)			-.152 (-2.072)			110.43	41.84
Male Wage		-.0387 (-.361)			.0356 (.46)		125.08	45.22
Hired Wage			-.1199 (-1.62)			-.08 (-1.69)	117.48	40.61
Marginal Effect of Female Labour on Risk	-1.02 (-1.44)		-1.02 (-1.43)	.455 (1.26)			6.011	81.00
Marginal Effect of Female Labour on Downside Risk	.00184 (.710)			-.0003 (-.260)			-219.03	2082.88
Marginal Effect of Male Labour on Risk		-1.02 (-1.44)			.455 (1.26)		-40.79	93.27
Marginal Effect of Male Labour on Downside Risk		.00184 (.710)			-.0003 (-.26)		-313.31	1189.62
Marginal Effect of Hired Labour on Risk			-1.02 (-1.44)			.455 (1.261)	41.15	75.31
Marginal Effect of Hired Labour on Downside Risk			.0018 (.710)			-.0003 (-.26)	929.37	1927.88
Adjusted R-Squared	-.0098	-.0098	-.0098	-.0098	-.0098	-.0098		

Results by Estimation Method

	Two Stage Least Squares			Three Stage Least Squares			Statistical Summary	
Variables	Female	Male	Hired	Female	Male	Hired	Mean	Standard Deviatio n
Degrees of Freedom	516	516	516	516	516	516		
System Weighted R-Squared				.0582	.0582	.0582		

Note: Hired wage is not disaggregated into male/female types and male/female wage refers to family wages.

Table 6.16: Summary of Uncompensated Food Demand Elasticities

Food Group	Uncompensated elasticities with respect to Price of					
	Potatoes	Beans	Maize	Sorghum	Fruits and Vegetables	Other Foods
Potatoes	-.953	-.0014	.0874	-.1141	.1702	-.02807
Beans	-.2466	-.6166	-.2104	-.0321	-.3699	-.00895
Maize	-.1713	-.5834	-1.22	.0532	-.2668	.00872
Sorghum	-.8338	.0962	.1499	-.8029	.3499	-.2218
Fruits and Vegetables	.4594	-.3306	-.0327	.2536	-1.19	.1636
Other Foods	.1375	.2005	.1916	-.0499	.2061	-.95

Table 6.17: Estimates of the Probability of Participation in Off-Farm Work

Variable	Coefficient Estimate	T-Ratio	Mean of Variable	Std. Dev. of Variable
Constant	-10.92	-6.2		
Sex (1=Male)	1.48	2.4	.487	.5
Worked in Organized Projects (1=yes)	4.86	4.8	.084	.278
Worked in agric. (1=yes)	1.32	1.1	.021	.144
Worked in Non-agric. (1=yes)	-.151	-.26	.035	.184
Years of Schooling	-.143	-.75	3.5	.59
Age of individual	.179	1.9	33.25	14.96
Age Squared	-.256	-2.2	13.29	12.03
Dummy round 1	2.59	3.2	.32	.47
Dummy round 2	1.88	2.4	.33	.47
Dummy Sector 2	.542	.87	.238	.43
Dummy Sector 3	1.072	1.83	.282	.45
Dummy Sector 4	-.058	-.072	.217	.412
Proportion of working women out of total workers in household	12.83	10.3	.089	.204

Log-Likelihood = -86.55 which is significant at the 0% level.
98% of the time the model predicted a zero when the actual observation was zero and 93% of the time the model predicted a one when the actual observation was one.

Table 6.18: Parameters used in Predicting Wages

Variable	Coefficient Estimate	T-Ratio	Mean of Variable	Std. Dev. of Variable
Constant	-67.52	-.898		
Sex (1=Male)	14.56	.743	.487	.5
Worked in Organized Projects (1=yes)	-29.06	-1.63	.084	.278
Worked in agric. (1=yes)	9.41	.42	.021	.144
Worked in Non-agric. (1=yes)	54.41	2.97	.035	.184
Years of Schooling	12.11	2.57	3.5	.59
Age of individual	5.85	2.28	33.25	14.96
Age Squared	-5.48	-1.64	13.29	12.03
Dummy round 1	78.17	2.04	.32	.47
Dummy round 2	82.35	2.17	.33	.47
Dummy Sector 2	4.44	.257	.238	.43
Dummy Sector 3	-17.19	-1.04	.282	.45
Dummy Sector 4	-7.91	-.443	.217	.412
Proportion of working women out of total workers in household	-39.46	-.864	.089	.204
Inverse Mills Ratio	28.13	1.2	.158	.321

Degrees of Freedom = 1611 with 262 as selected sample
Adjusted R-squared = .22
Log-likelihood = -1528

CHAPTER SEVEN
A MICRO-SIMULATION OF RWANDAN FOOD SECURITY POLICIES APPLIED TO KEY FOOD STAPLES IN GICIYE COMMUNE

7.1 Introduction

The previous chapter estimated the effect of a price change (in the presence of risk) on food and leisure consumption and labour allocation between farm and off-farm activities. The chapter also examined some of the determinants of the nutritional status of children as measured by three anthropometric indicators. This chapter summarizes the results of a micro-simulation exercise. The objective of the simulation exercise is to see how the relevant policy instruments would impact on risk and therefore, affect household food consumption, nutritional status, and leisure demand for different household types. This would have implications for food security in terms of which crops should have priority for which type of household. It would also affect the labour supply decisions for women in particular. This may have different effects for different household types and may in turn effect household food production and nutritional status of household members.

Micro-simulation allows for the incorporation of characteristics of the household which are crucial in determining demand patterns (Singh, Squire and Strauss). The structural equations to be used in the micro-simulation will be based on the econometric model outlined in Chapter 4 and the estimated results which are summarized in Chapter 5.

The policy instruments which will be used are: 1) floor price; 2) technological change that involves a decline in the level of risk and a decline in market level fixed transaction costs faced by these households. Transactions costs will be taken into account in the simulations by making use of the estimated link between prices paid and prices recieved by households in the study area (see Chapter 6 section 6.2.1):

Floor price: $lnP_S = a_0 + a(z) + blnP_{floor}$ **(7.1)**

Technological change: $lnP_S = a_0(1-t) + a(z) + blnP.$

7.2 Methodology

Additional equations will be estimated in order to determine how price changes affect changes in risk:

(7.2)

$$VAR(R) = \alpha_V + \beta_V P + e_V$$
$$SK(R) = \alpha_S + \beta_S P + e_S$$

This will yield estimates:

$$\frac{\partial VAR(R)}{\partial P} = \beta_V$$
$$\frac{\partial SK(R)}{\partial P} = \beta_S$$

The wage rate is endogenous in the model. Labour price changes may be simulated as follows:

$$MVP^0{}_L \equiv p^0 \frac{\partial Q}{\partial L}$$ with base MVP_L and

$$MVP^1 \equiv p^1 \frac{\partial Q}{\partial L} = p^0 \frac{\partial Q}{\partial L} \frac{p^1}{p^0}$$ which is the new MVP_L where p^1 and p^0 are output price indices for food staples. Given the reduced form equations, the (compensated pure substitution effect) of a percentage change in demand for food staples and leisure may be derived from the following equations:

(7.3)

$$\%\Delta S_i = \sum_{j=1}^{6} \%\Delta P_{ij}\epsilon_{ij} + \%\Delta VAR(R)\,\epsilon_{iV} + \%\Delta SK(R)\,\epsilon_{iS}$$

(7.4)

$$\%\Delta l_l = \%\Delta MVP_l\epsilon_{lW} + \%\Delta VAR(R)\,\epsilon_{lV} + \%\Delta SK(R)\,\epsilon_{lS}$$

where, S is the compensated demand for food staples

P is the price of food staples

ϵ_{ij} is the elasticity of the price of the jth good with respect to the ith food staple demand

$\epsilon_{iV}, \epsilon_{iS}$ are respectively the elasticity of demand with respect to risk and downside risk

ϵ_{lW} is the elasticity of leisure demand with respect to the shadow wage

$\epsilon_{lV}, \epsilon_{lS}$ are respectively the elasticities of leisure demand (for l=male, female members of the household) with respect to risk and downside risk where, the subscript i refers to the ith food staple and the subscript l refers to male/female total family leisure in a household.

The percentage change in the price of the food staple, shadow wage and risk variables are estimated as follows:

(7.5)

$$\%\Delta P = \frac{P^1 - P^0}{P^0}$$
$$\%\Delta MVP = \frac{MVP^1 - MVP^0}{MVP^0}$$
$$\%\Delta VAR(R) = \%\Delta P\epsilon_{PV}$$
$$\%\Delta SK(R) = \%\Delta P\epsilon_{PS}$$

the elasticity ϵ_{PV} is the change in the level of risk with respect to a one percent change in price. This elasticity is estimated from equation (7.1). The percentage change in calorie and protein demand was estimated as the percentage change in the level of calorie demand before and after the above changes in prices, risk and income.

Simulating the effect of a change in the output price of a food staple will have several direct and indirect effects. A change in the output price of a given staple will directly affect the price paid by households in the region; the marginal value product of labour of both males and females and the risk variable. A change in the output price indirectly affects consumption and calories through two sources: a) the change in the consumption price; b) the change in the risk variable. Leisure demand (for males and females) will also be influenced indirectly through the effect on the marginal value product of labour and the risk variable. Nutritional status will also be indirectly affected through the effect on calories consumed and leisure demand.

Technological change will involve two policy instruments. The first involves reducing the level of market level transaction costs (holding the level of risk constant). The second involves a direct change in the level of risk. This will have an effect on the level of income of the household. This in turn would translate to substitution in consumption (among food staples) and to the level of consumption (calories) and nutritional status. The change in risk would also directly affect leisure demand and therefore nutritional status is affected indirectly through calories, income, and leisure demand.

Once the effects of the above policies have been traced through its various outcomes then the final changes in the level of consumption, and nutritional status may be examined. Summaries of the mean level of changes by household types will shed light on the possible outcomes of these kinds of policies in this region of Rwanda in terms of: which household type is most affected in terms of food security, which food staple is the most important in managing the effects of production risk on consumption and the implication for the nutritional status of children in these households.

7.3 A Description of Policies to be Simulated

In 1988, the government of Rwanda implemented an effective floor price policy for major food crops. In Giciye region the major food crops are potatoes, beans, and sorghum. The floor price for these crops were 35 Frw/kg for beans, 22 Frw/kg for sorghum (Scott 1988:144). The floor price for potatoes of 12.75 Frw/kg potatoes used in the present study was taken from (Diaglogue 1986:66).

The reduction in market level transaction costs was simulated by a fifty percent reduction in the fixed market level transaction costs estimated in the previous chapter, with all other variables constant. A change in the household specific level of transaction costs was simulated by the complete elimination of the level of risk from the equation relating prices received to prices paid by households in Rwanda. The simulation will estimate the effect of these prices on calorie consumption by different household types, the effect on household leisure demand especially for females in the presence of risk and the implications for child nutritional status.

7.4 Simulation Results of a Floor Price in the Presence of Production Risk

An increase in price affects consumption directly through the substitution effect and indirectly through its effect on risk and income. Therefore, depending on how prices effect the level of production risk and average income, different household types may actually consume more of a good than less (see Chapter 4). The results of the compensated change in consumption from imposing floor prices on the three most important staple crops are summarized below.

7.4.1 Results of the Floor Prices Policies

The results of imposing a floor price policy on the individual crops (with all other variables held fixed) are summarized in Figures 7.1 to 7.5. The results show that all households consume less of the given good when the floor price is imposed. However, incorporating risk gives rise to differences in substitution patterns across household types.

Potato Floor Price. Figure 7.1 shows that a floor price on potatoes causes all households to consume less of the food staples and more of the non-staple foods. A floor price policy in the presence of production risk causes buyer households to consume relatively less potatoes and sorghum. Non-buyer households consume more potatoes in the absence of risk. Non-buyer households consume less fruits and vegetables and a little more of other foods. This result for non-buyer households is however not significant.

Bean Floor Price. In Figure 7.2, a floor price on beans causes all households to consume less beans. Introducing risk into the analysis alters the substitution pattern of consumption for the various household types as compared to the case without risk. In the absence of risk, a floor price on beans causes all households to consume more potato, maize and sorghum and less beans and fruits and vegetables. In the presence of risk, a floor price policy on beans causes buyer households to consume more potatoes, fruits and vegetables, and other foods and less of the other staples. However, the substitution toward potatoes is greater in the absence of risk. In addition, an absence of risk causes buyer households to consume more sorghum relative to the case without risk. Non-buyer households substitute away from sorghum toward maize in the presence of risk. In the absence of risk these households also consume more sorghum.

Sorghum Floor Price. Figure 7.3 summarizes the effect of a floor price on sorghum. A floor price on sorghum causes all households to consume less sorghum. In the absence of risk, all households substitute toward fruits and vegetables and away from sorghum. However, non-buyer households substitute more toward fruits and vegetables and away from sorghum than do buyer households. In the presence of risk, buyer households substitute more away from potatoes and other foods. Non-buyer households substitute more away from the other staples and consume relatively more sorghum as compared to the case when risk is absent.

Combined Floor Price Policies. When the floor price policies are analyzed in unison, one finds that all households consume less of the food staples and more of the non-staples. The non-staples are relatively more expensive but are less risky (Figure 7.4). Buyer households consume relatively more sorghum and less of the other food staples and non-staples in the absence of risk (as compared to the case with risk). For buyer households, the existence of risk causes these households to substitute more strongly to the less risky non-staples. All households consume more sorghum in the absence of risk. Buyer households, in addition to consuming more sorghum also consume more potatoes in the absence of risk.

The Total Effect of Floor Price Policies on Household Consumption. This section summarizes the total effect of the floor price policies in the presence of risk. This total effect combines the income as well as the substitution effect of a change in price (both in the presence and absence of risk). Household consumption in this case is aggregated by using the calorie and protein content of the foods. The results are graphically summarized in Figure 7.5. The floor price policies have significant negative effects for total household consumption of calories and protein in buyer households especially in the presence of risk. Marginal buyer households fare a little better when compared to net buyers in the presence of risk. Non-buyer households experience a larger availability of calories and protein in the presence of risk. These results support the hypothesis that seller households take advantage of the negative correlation between regional prices and the level of output in managing production risk.

7.4.2 Results of Transaction Costs

Figure 7.6 summarizes the results on household consumption of a reduction in transaction cost.

Potato transaction Costs. A 50% decline in the potato transaction cost leads to increased consumption of the food staples by all households. These gains would be higher across all households if risk was eliminated. The reduction of transaction costs associated with potatoes causes non-buyer households to consume relatively more of other foods and less of sorghum than do buyer households. This is the case whether risk is present or not. These results are summarized in Figure 7.6A.

Beans Transaction Cost. In Figure 7.6B, a 50% reduction in the fixed market level transaction costs for beans causes all households to substitute toward sorghum. Buyer households consume less of the other foods and more beans and sorghum. Non-buyer households consume less beans and more sorghum.

Sorghum Transaction Cost. Figure 7.6C shows that a reduction in the transaction cost for sorghum causes all households to consume less fruits and vegetables and more staples and other foods. Buyer households consume relatively more potatoes and other foods than non-buyer households. Non-buyer households consume relatively more beans and maize than buyer households.

Combined Reduction in Transaction Costs. A combined reduction in transaction costs of potatoes, beans and sorghum leads to all households substituting toward more consumption of food staples and less of the non-staples. This result is depicted in Figure 7.6D.

The Total Effect of Reduced Transaction Costs on Household Consumption. The total change in calorie and protein consumption by the various policies analyzed in this study are summarized in Figure 7.7. A fall in transaction costs is the most effective in improving the level of consumption of buyer households. The floor price policies in the presence of risk is the most detrimental to the calorie consumption of buyer households.

As expected, the marginal buyer household manages the impact of production risk on consumption better than the buyer household.

7.4.3 The Effect of Various Policies on Household Leisure Demand

Figure 7.8 summarizes the results of the effect of various policies on leisure. Both males and females in the household work harder with the existence of a floor price policy. However, females in the household work harder than males. Females in buyer households work hardest with the imposition of a floor price policy in the presence of risk. The presence of risk does not significantly effect household labour supply. A fall in transaction cost has little effect on household labour supply.

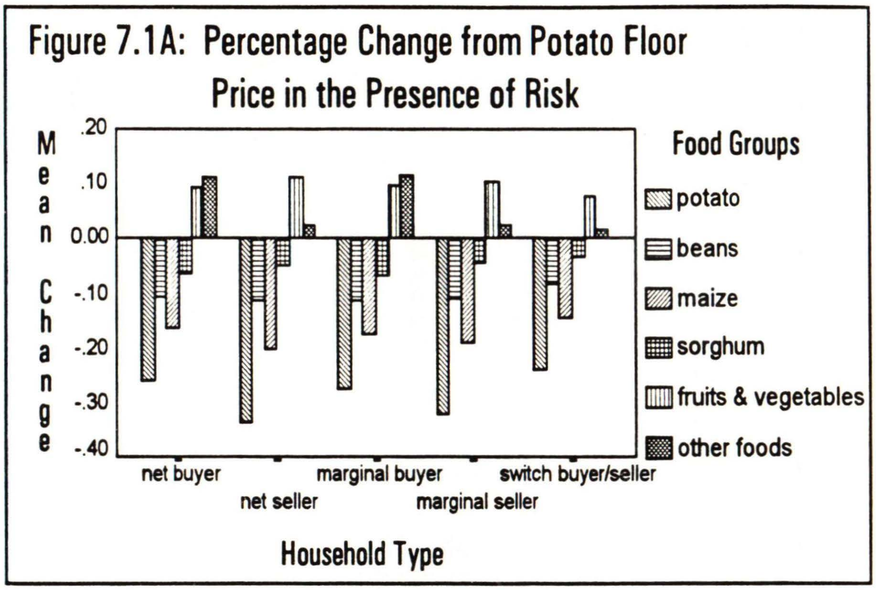
7.4.4 The Effect of Various Policies on Child Nutritional Status

Figure 7.9 summarizes the long-term effect of the various policies on household welfare. All household are adversely effected by a floor price policy. The results suggest that a floor price policy has more adverse consequences for household welfare than the presence of production risk. A combined floor price on food staples has the most adverse effect on the height for age of children in buyer households. The presence of risk increases this adverse effect for buyer households. Figure 7.9B shows that a reduction of transaction costs does not have a strong effect on the nutritional status of children in the household.

7.5 CONCLUSION

The above simulation exercise highlight several important results of risk. The substitution pattern among food staples suggests that in the absence of risk, all households would consume relatively more sorghum and less non-staples. Buyer households would consume more potatoes. Eliminating risk causes an increase in nutrient intake for all households, however it causes very marginal changes in the level of labour supply. This marginal change, however still has an effect on the nutritional status of children in the household. A reduction in transaction costs leads to greater gains by all households (especially buyer households) in terms of nutrient intake and nutritional status of children. Although, the effect on the weight for height indicators for children in buyer households suggests that these households will be most adversely effected in the short-run. The above exercise also suggests that reducing market level transaction costs (by building roads for example) is more efficient in reducing prices paid by households and therefore would do more to encourage commercialization and improve food security (especially for buyer households which constitute a major proportion of the poorest households in Rwanda) than a floor price policy.

Figure 7.1: Substitution Effect of Potato Floor Price Policy (of 12.75 Frw/kg) on Household Consumption by Household Type



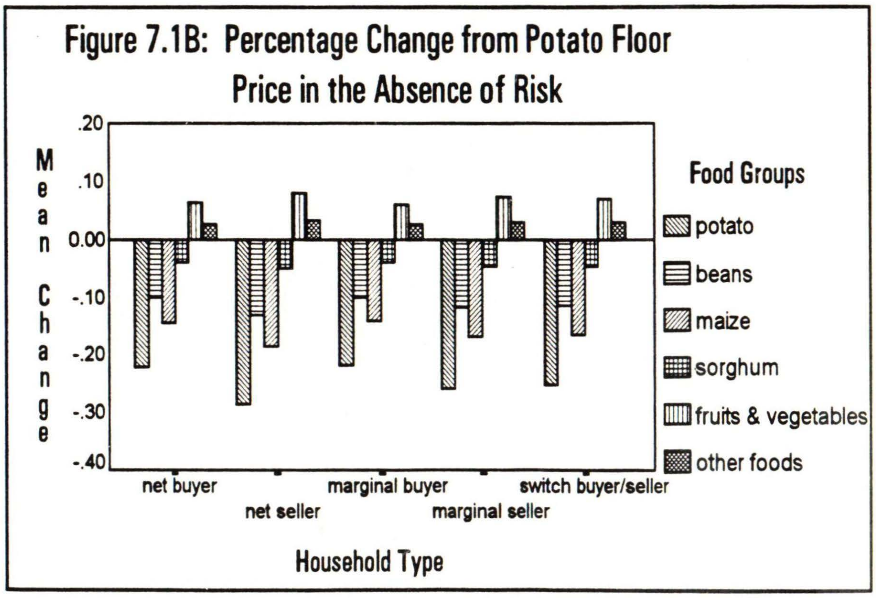
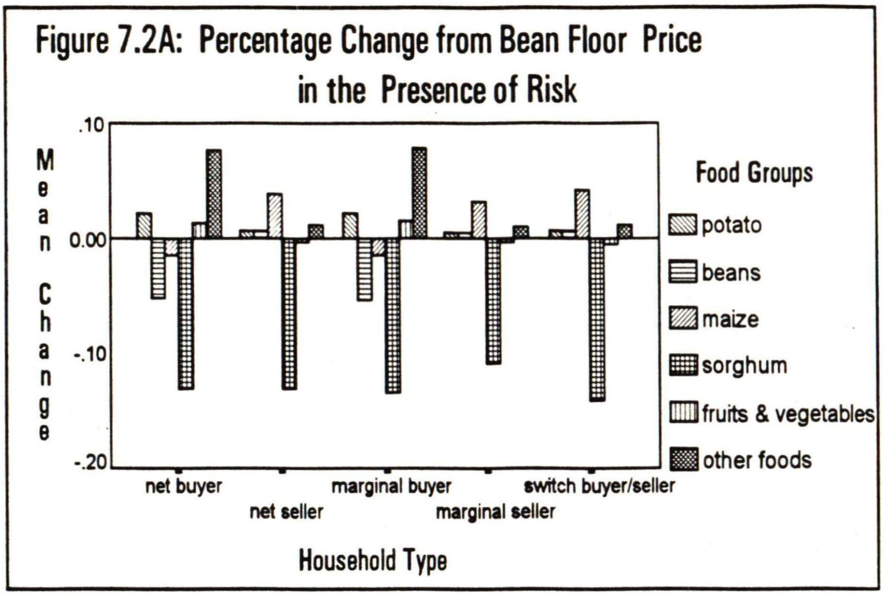


Figure 7.2: Substitution Effect of Beans Floor Price Policy (of 35 Frw/kg) on Household Consumption by Household Type



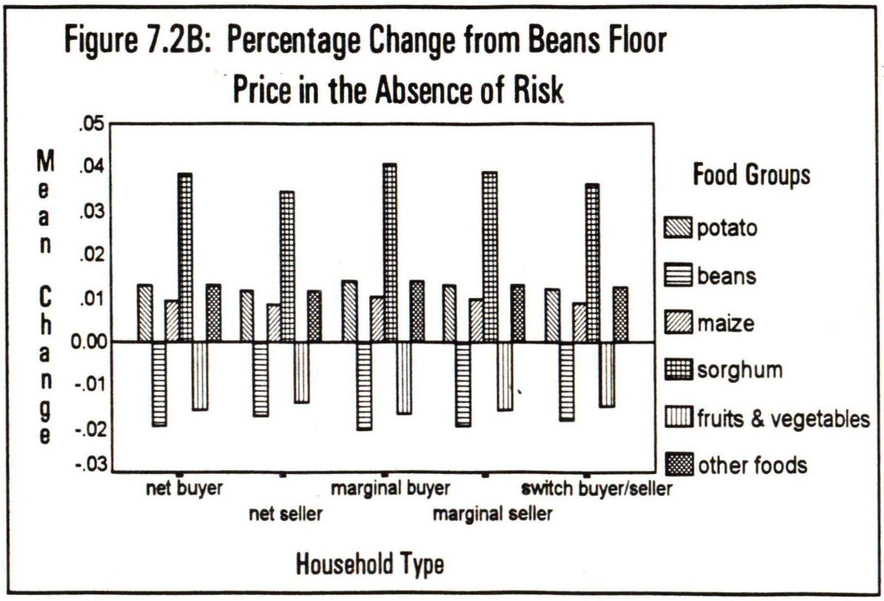


Figure 7.3: Substitution Effect of Sorghum Floor Price Policy (of 22 Frw/kg) on Household Consumption by Household Type

Figure 7.3A: Percentage Change from Sorghum Floor Price in the Presence of Risk

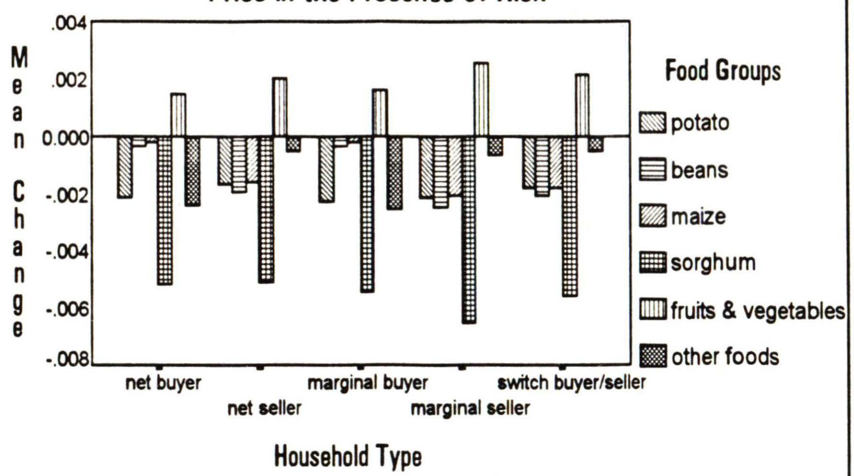


Figure 7.3B: Percentage Change from Sorghum Floor Price in the Absence of Risk

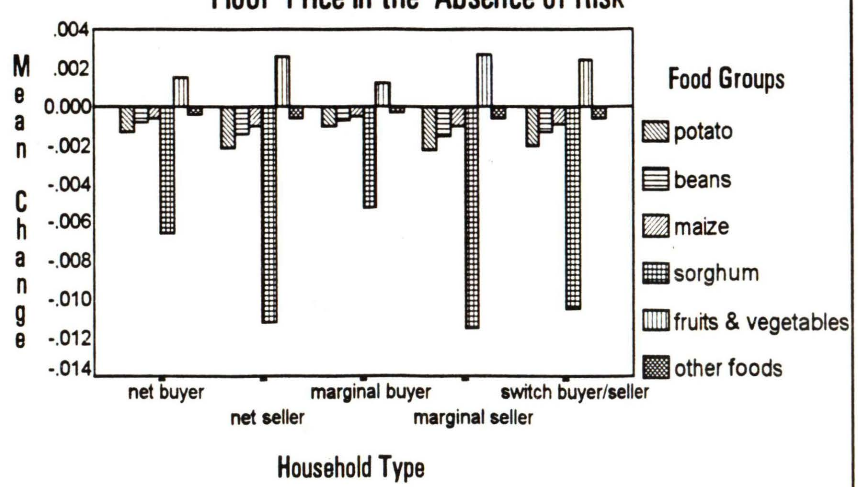
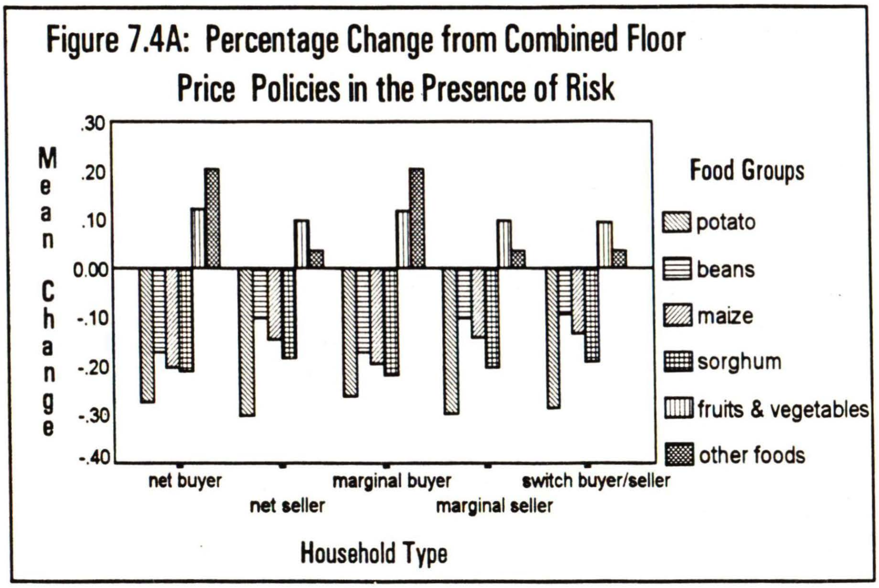


Figure 7.4: Substitution Effect of Combined Floor Price Policies on Household Consumption by Household Type



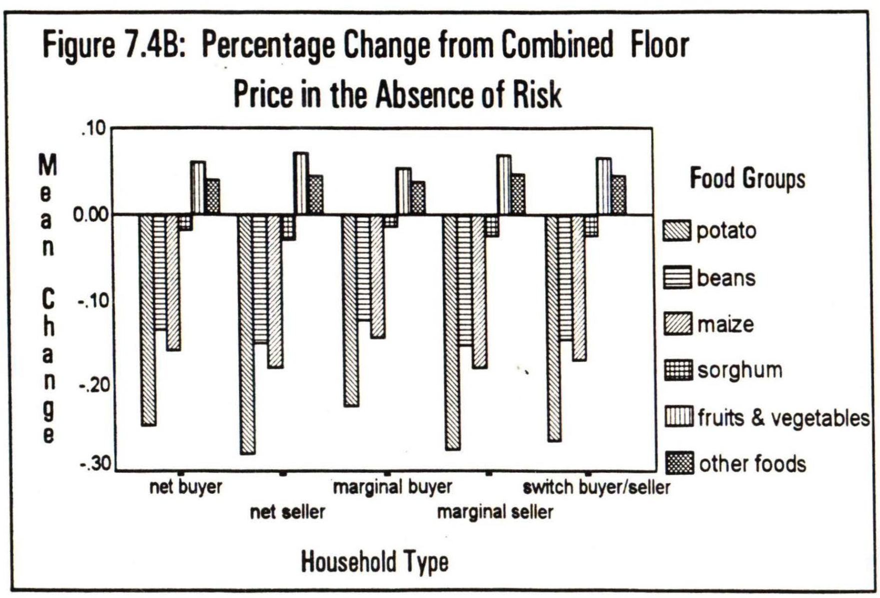
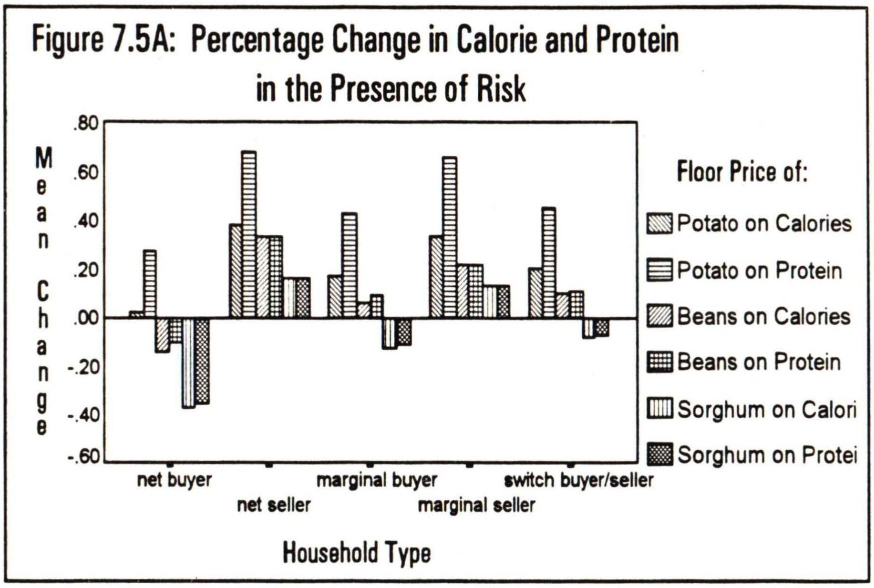


Figure 7.5: The Effect of Floor Price Policies on Nutrient Consumption by Household Type



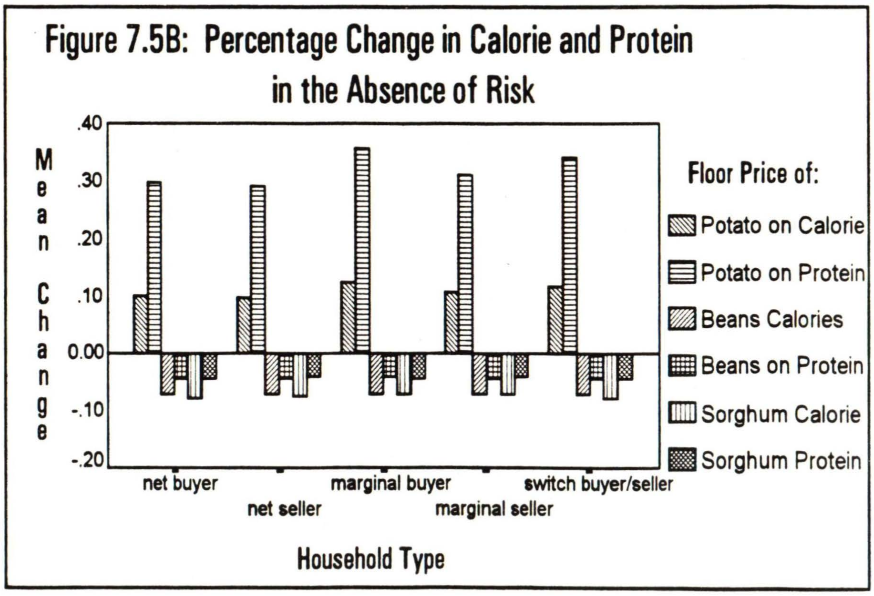
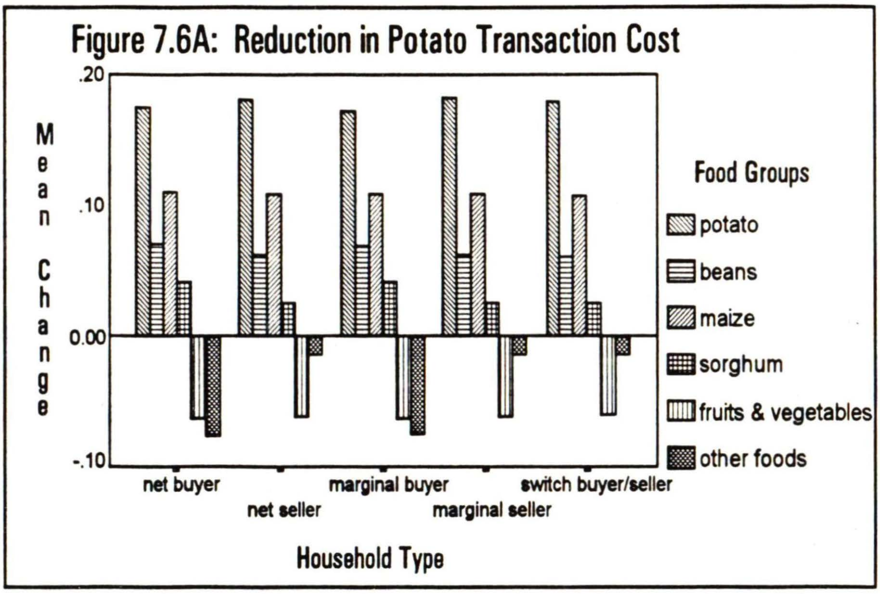


Figure 7.6: Substitution Effect of a 50% Reduction in Transaction Costs in the Presence of Risk by Household Type



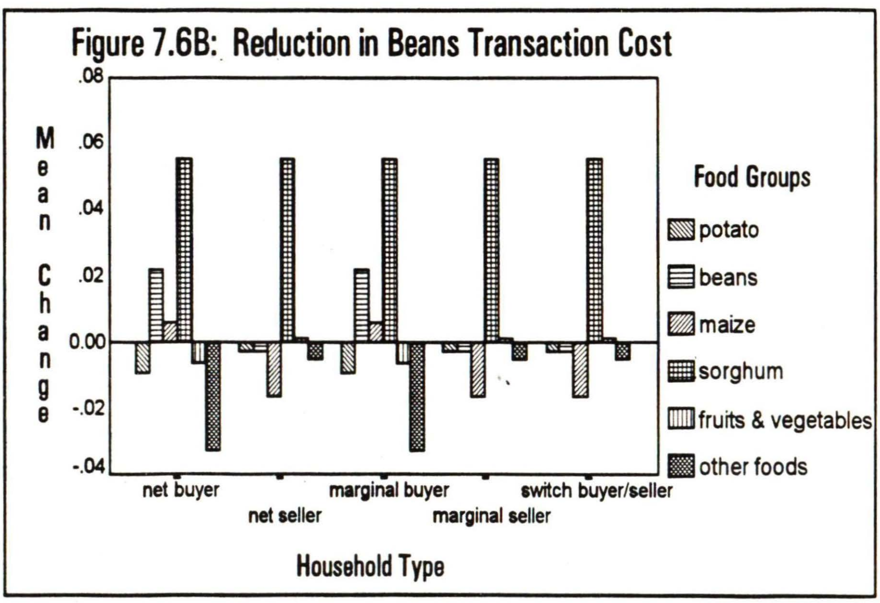
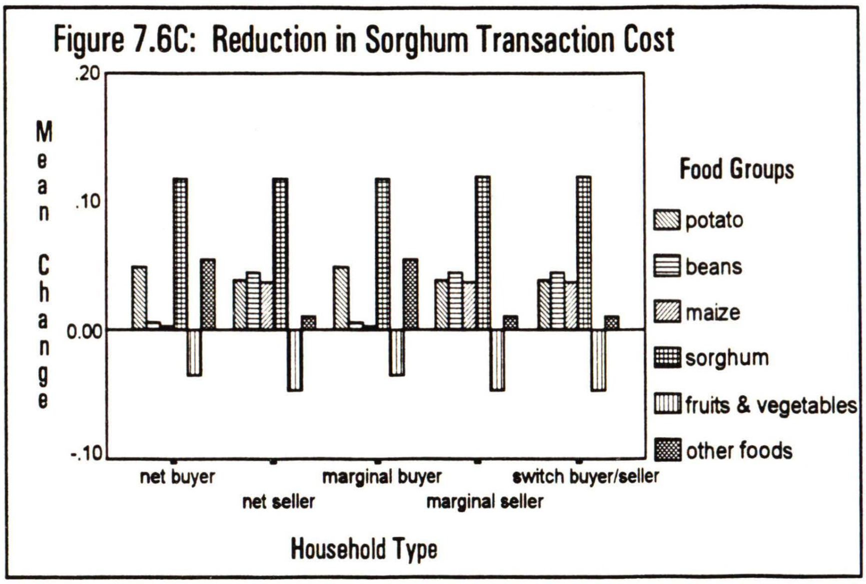
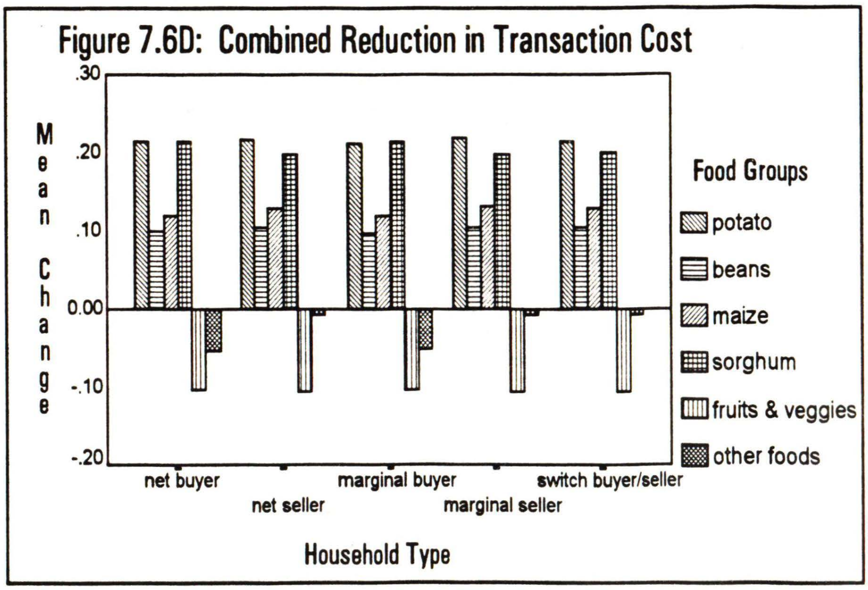


Figure 7.6 (cont'd): Substitution Effect of a 50% Reduction in Transaction Costs in the Presence of Risk by Household Type





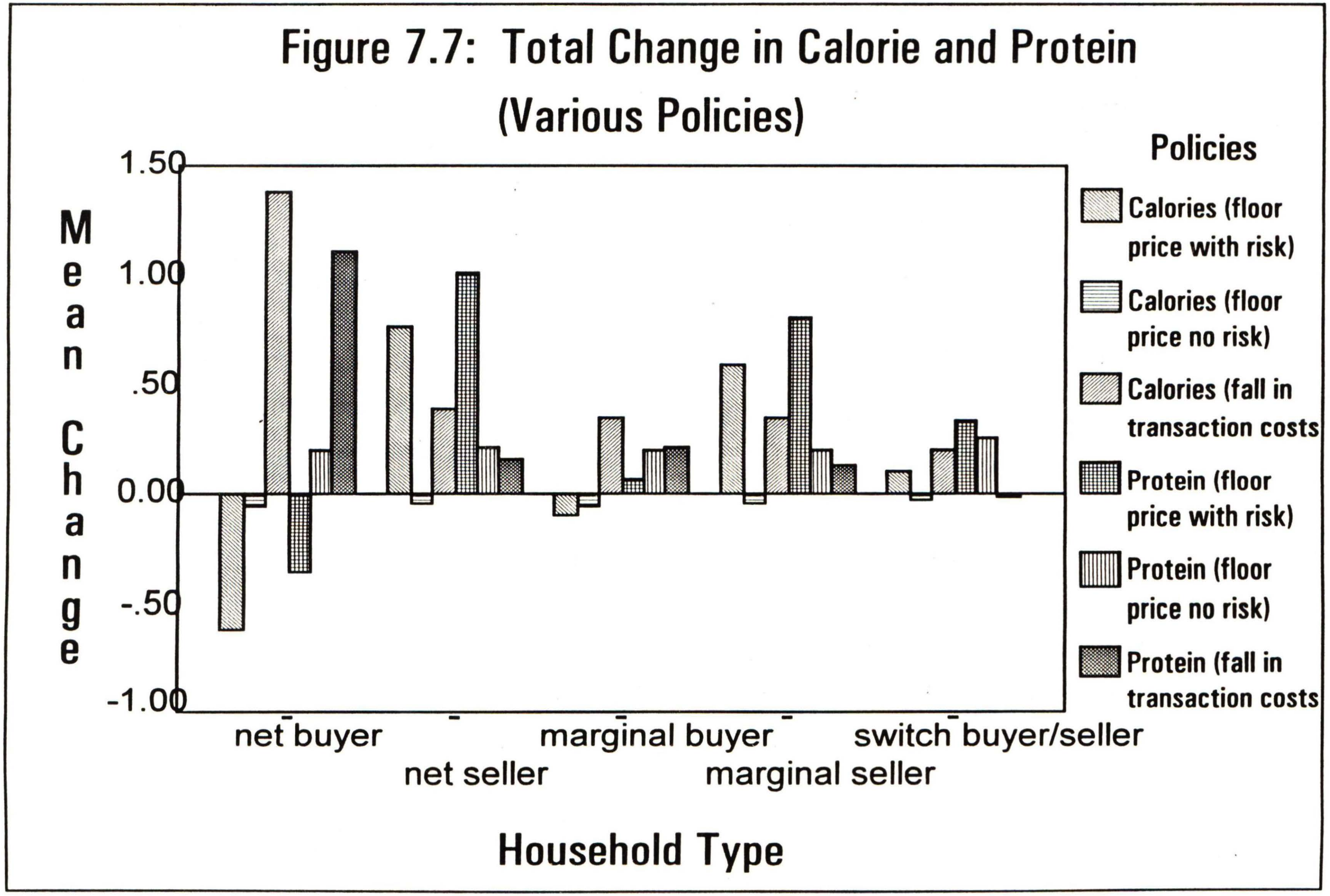
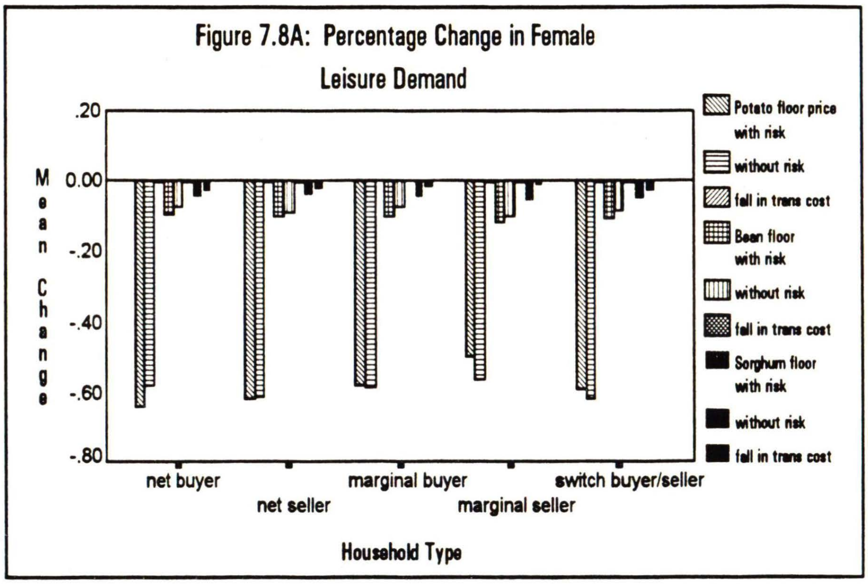


Figure 7.7: Total Change in Calorie and Protein
(Various Policies)
Mean Change
1.50
1.00
.50
0.00
-.50
-1.00
net buyer
net seller
marginal buyer
marginal seller
switch buyer/seller
Household Type
Policies
Calories (floor price with risk)
Calories (floor price no risk)
Calories (fall in transaction costs
Protein (floor price with risk)
Protein (floor price no risk)
Protein (fall in transaction costs

Figure 7.8: The Effect of Various Policies on Household Leisure Demand by Household Type



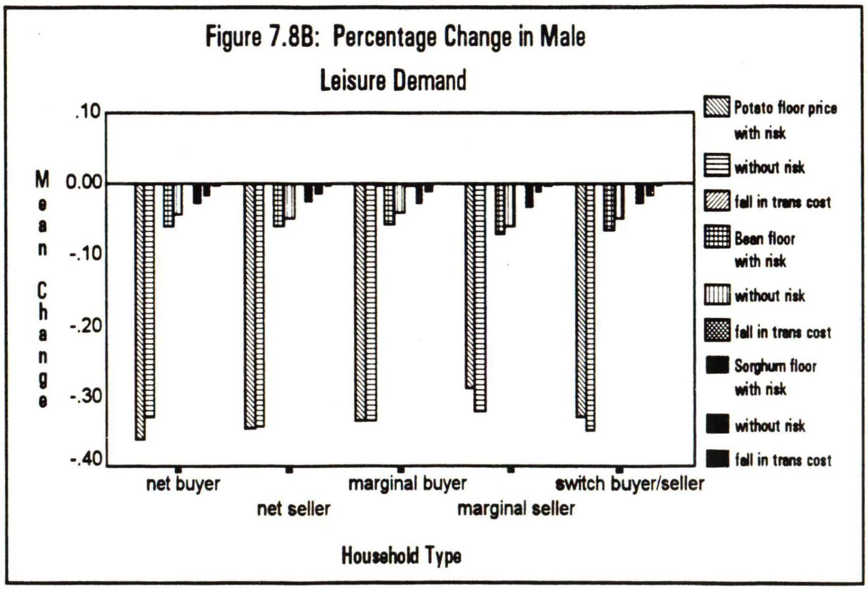
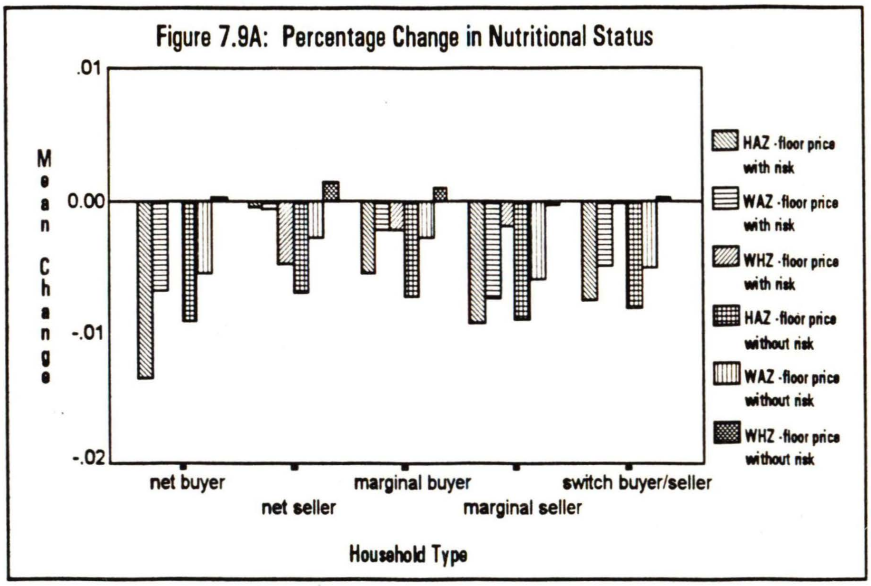
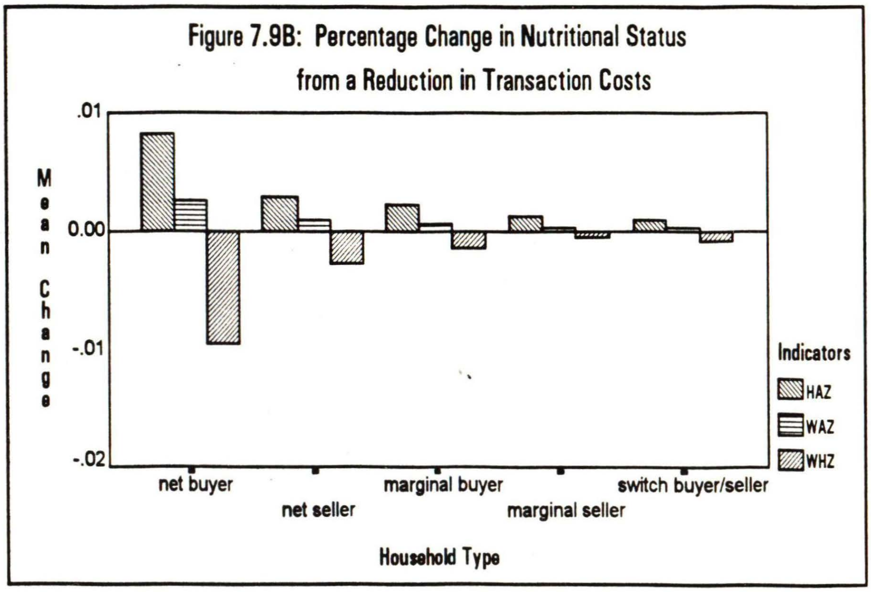


Figure 7.9: The Effect of Various Policies on Nutritional Status by Household Type





CHAPTER EIGHT
CONCLUSIONS AND POLICY IMPLICATIONS

8.1 Summary of Results

The objective of this study was to examine the effect of production risk on consumption, resource allocation decisions and the welfare of agricultural households in Rwanda. The semi-subsistent nature of these households is characterized by the dependence of production decisions on consumption decisions. In order to accomplish this it was necessary to develop a framework that accounted for this semi-subsistent nature. With well developed insurance and credit markets, production decisions can be made independently of consumption decisions. This is not the case in Rwanda. Underdeveloped insurance and credit markets, coupled with extremely high storage costs means that households must rely mainly on other sources of income in order to diversify production risk.

This study found off-farm labour income to be an important component of income in Rwanda. Males supply the majority of labour to off-farm activities and females to food production. However, the high population density in the area means that not all individuals are able to work as much as they would want off-farm. This rationing of family labour supply in the labour market leads to the simultaneous determination of production and consumption decisions in Rwanda. Previous models which examine the effects of risk within an agricultural household framework have assumed sequential decision making. The current study developed a framework which allowed for the possibility of the simultaneous determination of production and consumption decisions.

The moment based method developed by Antle was modified to allow for the possibility of rationing in the labour market. This was used to estimate the extent of production risk, and the risk attitudes of agricultural households in the area. Production risk was found to be a real concern to agricultural households. The results show that households are risk averse and that there are positive costs associated with production risk in the area.

The above framework was then used to determine the effect of risk on household consumption and welfare. It also examined the effect of risk on family labour disaggregated by gender. The conclusion was that risk had a different effect on male and female household labour decisions. It was found that risk was a major determinant of the allocation of female labour within the household, but was not a significant determinant in the allocation of male labour. In seller households (which are relatively more commercialized) males worked harder at the margin than females. In buyer households (which are relatively more subsistence oriented) females worked harder at the margin than males.

In terms of food consumption, the existence of risk causes buyer households to consume more beans than they would in the absence of risk. A micro-simulation exercise showed that a reduction in production risk would cause buyer households to consume relatively more potatoes and sorghum than they would in the absence of risk. A floor price policy on the major food staples (potatoes, sorghum, and beans) causes all households to consume less of the food staples (potatoes, sorghum, beans and maize) and relatively more of the non-staples. Buyer households were the most adversely effected by risk. A reduction in risk would cause an increase in nutrient intake for all households. A reduction in transaction costs leads to greater gains by all households in terms of nutrient intake and nutritional status of children. Reduction of transaction costs faced by households was found to be more effective in improving calorie and protein intake for households in the study than a floor price policy.

8.2 Implications of Results for Policies Designed to Encourage Commercialization and Technological Change

Beans and potatoes should be targetted for increased commercialization and technological adoption. In Rwanda, beans and potatoes are important food staples. Potatoes are a relatively cheap source of calories but are relatively more risky to produce. Beans are an important source of protein for rural households. It is a relatively more expensive food staple which is relatively less risky to produce than potatoes. Sorghum beer production is an important source of income supplementation for agricultural households. A significant amount of sorghum is purchased for this purpose in the study area. The level of direct sorghum consumption is low across all income quartiles (von Braun 1991:73). Consumption of sorghum beer is tied to ceremonial customs and events (Loveridge 1988). Targetting beans and potatoes for increased commericialization would have a greater impact on food security for the poorer households.

Most households in Giciye commune are net buyers of beans. This region of Rwanda is a net importer of beans from the other regions and neighbouring countries. Net sellers of beans in the region are relatively better off (in terms of food availability) than net buyers of beans in Rwanda. Net buyers of beans tend to be more food insecure, as measured in terms of calorie availability, than net sellers. A reduction in transaction costs would contribute to a decline in prices that buyer households have to pay in this region. In addition, a reduction in risk would cause all household types to consume relatively more potatoes, beans and sorghum. These results suggest that government investment to improve institutions (for credit and crop insurance especially for potatoes) and infrastructure (such as roads) would be most effective in terms of improving food security of rural households than direct price interventions.

In the past, governments of Less Developing Countries (LDCs) have assumed that all agricultural producers are net sellers of food. As a result, this has been used as the criteria in the targetting of price policies. Past studies (Loveridge 1988) have shown that this assumption leads to incorrect predictions of the possible outcomes and effects of policies on agricultural households. This study shows that not explicitly incorporating production risk into the analysis under estimates the degree to which buyer households are adversely effected by floor price policies. Therefore, there is a definite need to properly classify households in rural areas for targetting of government policies.

The study also yields further empirical justification for the active involvement of women in the development process. In Rwanda, women in rural areas are the ones most involved in food production. This study shows that risk has a greater effect on the labour allocation decisions of females than on men. This in turn has implications for the nutritional status of children within the household, as mothers' leisure time more significantly effects the child's nutritional status than the males'. Therefore governments concerned with food security need to also target the producers of food in order to help them in effectively managing the risks they face.

8.3 Suggestions for Future Research

The first obvious direction for future research would be to make the model dynamic. This may aid in explaining the low storage levels observed in the area. The greatest percentage of harvest are sold right after harvest in Rwanda. It would be interesting to see how the timing of sales is determined by the degree of production risk. This would require a longer panel series. One year of quarterly data may be enough if roughly the same number of households are surveyed.

In the current study it was not possible to dissaggregate production by crops in order to see what role risk played in terms of which crops are grown. This was because of the high degree of inter-cropping in the area. The data was collected in such a way that inputs to production were not differentiated by crop grown. This study gets around this problem by estimating an aggregate production function. In addition, the estimation of input demand and output supply functions as a function of production risk could be another future area of research. This would answer the question of how production risk impacts on input demand and suggest possible areas of interest in terms of input price policies.

Finally, it would be interesting to repeat this study for other countries in Africa, Asia and Latin America. Generally, in Africa females are responsible for food production whereas males are responsible for the production of commercial crops. It would be interesting to see if risk has the same effect on female labour allocation in other African countries. It would also be interesting to see if risk has the same effect on female labour for other societies where the roles of males and females in agricultural production is different from that in Africa.

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