University of Alberta

Household Behaviour Models of Smallholder Agricultural Producers in Zimbabwe: A Risk Programming Approach

by

Christopher Zindi ©

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DEDICATION

To my mother, and in loving memory of my father and sister, Erica.

ABSTRACT

This thesis uses stochastic optimization models to examine the behaviour and risk attitudes for smallholder producers in Zimbabwe. The objectives of the study were to investigate: 1) whether leisure should be modelled explicitly in household models; 2) risk preferences for a sample of smallholder producers; 3) whether results of partial sector household models are improved by increasing numbers of sectors modelled; 4) whether results of household models are improved by increasing numbers of risk parameters modelled; and 5) the potential for using household models in policy analysis. A Utility Efficient risk programming model was used to study household behaviour. The study uses household-farm level data for a sample of 199 households in Chivi District.

Results of investigations into whether leisure should be modelled explicitly in household models showed that leisure appeared to be relatively constant throughout the year. Results suggested that leisure need not be modelled explicitly.

Results of risk preference estimation showed that, apart from indeterminate cases, all wealth groups generally displayed high levels of risk aversion when compared to previous literature. Since previous studies were largely based on developed country studies, high values obtained in this study seemed plausible given the low incomes in the study area.

The issue of whether partial sector household models are improved by increasing the number of sectors modelled was investigated by comparing results for double and tri-sector models. Inconclusive results could be attributed to tradeoffs regarding complexities in modelling an extra sector (i.e., woodlands) versus the added completeness of incorporating this sector.

The issue of whether results of household models were improved by increasing the number of risk parameters modelled was investigated by comparing results for single and sector specific risk parameter models. There was little difference in results by wealth group suggesting that household behaviour could be adequately modelled using a univariate utility function.

Results showed that such models may be successfully applied to model a policy situation. The model correctly predicted that an increase in cash would be directed towards increasing dryland agricultural activities and that cash amounts would have to be increased significantly to impact household livelihoods.

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CHAPTER 1

Introduction

1.1 Background and Problem Statement

Agriculture in developing economies is characterized by risk and uncertainty. The major types of risks faced by smallholder agricultural producers include: climatic variation; human morbidity and mortality; animal morbidity and mortality; the loss of major income sources (e.g., through unemployment within the family); equipment failures; institutional risk (e.g., uncertainty with respect to the policy environment) and price shocks (Cavendish 2003, Fleisher 1990). In most developing countries, agriculture remains a principal source of income for the majority of the population, an important earner of foreign exchange, and a central concern of government policy makers (Singh, Squire and Strauss 1986). In Zimbabwe's smallscale farming sector, agriculture is characterized by low productivity and high risk of yield failure (Hedden-Dunkhorst 1997). Uncertainty with respect to weather conditions makes resource allocation decisions difficult for smallholder farmers in developing countries.

Faced with a risky situation, rational firms seek to allocate resources optimally given their risk preferences. Wolgin (1975) notes that small-scale farmers in Kenya, under conditions of uncertainty, behave as efficient, risk-averse entrepreneurs. However, decisions of farmers are affected by risk and preferences. The adoption of innovations with relatively high levels of risk and/or uncertainty would be less likely, or would occur on a smaller scale if a majority of farmers are risk averse (Ghadim and Pannell 1999).

Fafchamps (1999) notes that one of the ways in which the rural poor cope with risk is by choosing activities and techniques of production that keep income variations to a minimum. One potential consequence of such a strategy is that the poor may resist technological innovations that raise the mean and variability of income at the same time (Fafchamps 1999). The acquisition of benefits from new technology may therefore be slower in the presence of risk. Becker (1990) notes that the combination of different labour resources, alternative off-farm employment opportunities and risk perceptions towards different technologies determine labour allocation in smallholder subsistence households and the willingness to adopt land-saving and yield-increasing technologies.

Risk attitude has been identified as an important parameter influencing production and consumption decisions (Binswanger 1980; Hazell 1982). Disregarding the possibility of risk-averse behaviour in agricultural models can lead to overestimation of output levels of risky enterprises, overly specialized predicted cropping patterns, and biased estimates of the supply elasticities for individual commodities (Hazell 1982). Accordingly, excluding risk in agricultural decision models may result in incorrect predictions of marketed surplus, supply response and technology choices, giving an erroneous basis for policy recommendations. It therefore appears that understanding household risk perceptions is central to understanding production, consumption, marketing and technology adoption decisions of smallholder agricultural producers.

To date, few studies have integrated risk in modelling the behaviour of smallholder agricultural producers in developing countries. The objective of this study is to address this knowledge gap by presenting models of the microeconomic behaviour of smallholder agricultural producers within a risk programming framework. It is hoped that the results of this study will provide an improved understanding of household behaviour given the risky economic and physical environments in which they operate. The study may help policy makers and extension agents better understand whether proposed policy changes and project interventions will increase livelihoods of smallholder agricultural households. It is also hoped that the results will provide information of value to governments and international agencies in terms of improving their ability to assist the rural poor to better deal with risk.

1.2 Objectives of the Study

The general goal of this study is to simulate the behaviour of smallholder agricultural producers in a developing country using a risk programming approach. Five broad categories of research questions guide this study.

(a) **Does leisure have to be explicitly modelled in household models?** There is an ongoing debate in the household model literature as to whether leisure should be explicitly modelled. There are two schools of thought regarding the manner in which leisure should be treated in the empirical analysis of household models[1]. This study will

1 Section 2.3.2 provides a detailed discussion on the debate pertaining to modeling leisure in household models.

contribute empirical information to this debate, using a case study approach, by examining whether it is important to model leisure explicitly.

(b) **What types of risk preferences are exhibited by smallholder agricultural households?** Are decision-making households risk averse, and if so, to what degree? The study proposes to recover risk preferences for a sample of smallholder agricultural households. Understanding risk preferences may shed light on production, consumption and marketing behaviour of smallholder agricultural households.

(c) **Are results of partial sector household models improved by increasing the number of sectors (e.g., agriculture, woodlands etc) being modelled?** A specific objective of this study is to investigate whether results of partial sector models are improved by increasing the number of sectors being modelled. Results of household models with different numbers of sectors being explicitly modelled will be compared. This will provide an improved understanding of whether there are benefits to be gained by increasing the number of sectors modelled.

(d) **Are results of household models improved by increasing the number of risk parameters being modelled?** A specific objective of this study is to investigate whether results of household models are improved by increasing the number of risk parameters being modelled. Results of single risk parameter models will be compared with those for multiple risk parameter models. This will provide an improved understanding of whether there are advantages in pursuing multiple risk parameter models.

(e) **How can household models be used to investigate development initiatives?** What is the impact of interventions or development projects on livelihoods of smallholder agricultural producers? In smallholder systems in semi-arid areas, financial capital in the form of cash is severely constrained; cash received is soon allocated and spent (Mortimore 1998). An objective of this study is to simulate particular policy interventions with household models. The possible impact of an intervention in the form of a micro-credit scheme on livelihoods of smallholder agricultural producers is studied, using a Zimbabwean case study.

1.3 Organisation of the Thesis

This study is organized as follows. Chapter Two presents a review of the theoretical framework and empirical issues relevant to this study. The chapter concludes by highlighting the nature of analyses to be undertaken. Chapter Three describes the structure of empirical household models to be used. Chapter Four provides a description of the data used in this study and an overview of some key characteristics of sample households. Chapter Five presents results of an investigation into whether leisure should be explicitly modelled. Chapter Six presents a calibration of the household models. Chapter Seven provides an analysis of model results. Chapter Eight presents results of policy simulations with household models. Finally, Chapter Nine provides a summary of the results, conclusions, limitations of the study, and areas for future research.

CHAPTER 2

Literature Review: Theoretical Framework and Empirical Issues

2.1 Introduction

This chapter provides a review of the literature relevant to this study. The chapter starts with a presentation of the theoretical framework that forms the basis of this study; expected utility[2] theory. This is followed by a discussion of risk preferences. The theory of expected utility is then cast within a household decision-making framework. The utility-efficient programming model, used in this study, is then discussed. Empirical issues relevant to this study are then presented. The chapter ends with a discussion of issues to be analyzed in this study.

2.2 Theoretical Framework

Theoretical issues relevant to this study include utility theory, risk, expected utility theory applied to a household decision-making framework and the analytical model.

2 When the outcome of an action is uncertain, and the possible outcomes involve different levels of utility, the expected utility of the action is the weighted sum of the utility levels of the possible outcomes. The weight for each of the possible utility levels is the probability of occurrence for the associated outcome (Kopp and Smith 1993).

2.2.1 Expected Utility Theory

Expected utility (EU) theory provides the principal theoretical basis for choices under uncertainty (McCarl and Spreen 1997) and is the theoretical foundation of this study[3]. The EU approach provides a suitable framework for explaining behaviour of producers, including the measurement of risk attitudes (Buschena and Zilberman 1994). Although expected profit maximization is an alternative approach to modelling household behaviour under risk, it is generally considered to be a secondary objective of smallholder agricultural households. Other objectives such as achieving household food security are considered more important. Hazell and Norton (1986) note that farmers often prefer farm plans that provide a satisfactory level of security even if this means sacrificing income on average. Wolgin (1975) argues that a farmer for whom risk is an important consideration will maximize expected utility rather than expected income. Maximization of expected utility of consumption appears to be a plausible objective for smallholder agricultural households.

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3 It is assumed that the expected utility hypothesis characterizes the behaviour of the decision-making household. The expected utility hypothesis characterizes the following solution for an uncertain decision problem (Robison 1982): (a) identify the action choices available and the possible states of nature under which action consequences may be experienced; (b) assign probability weights to the states of nature consistent with the probability calculus; (c) identify the consequence of the i^{th} action choice under each jth possible state of nature and assign to each a preference measure, a utility value; (d) calculate the expected utility index for each action choice; and (e) implement the action choice with the highest index.

Within the EU framework, utility is used to "quantify" preferences. A utility function relates the level of a relevant measure, such as income or wealth, to utility or satisfaction. Expected utility theory asserts a set of axioms[4] about how individuals order risky prospects, and then deduces the existence of an ordinal utility function U(Y) which associates a single real value of utility or "satisfaction" to any value of measure output Y (Hazell and Norton 1986). The EU model infers that rational firms who obey the axioms should, or do, choose actions that maximize their expected utility (Barry 1984). The axioms are sufficient to guarantee that there exists a utility index such that the ordering of risky alternatives by their expected utilities fully coincides with the person's actual preferences[5].

The EU theory is based on ordinal preference indices (Hazell 1982) that can be used to rank utility derived from different goods and services. The EU model views household decision-making as a choice between risky alternatives with each outcome being associated with a different state of nature. Following Barry (1984), the expected utility for a risky action, a_j, assuming n alternative states of nature, can be evaluated as:

$$(2.1) \quad (EU) = \sum_{i=1}^{n} U[C(\theta_i, a_j)]p(\theta_i)$$

where $C(\theta_i, a_j)$ represents the level of consumption for the i^{th} state of nature (θ_i) and j^{th} action (a_j); $U[C(\theta_i, a_j)]$ represents the utility associated with this level of consumption;

4 These axioms deal with ordering and transitivity, continuity and independence of choices (Barry 1984).
5 If expected utility indices are to correctly order action choices for an individual, several conditions must be met (Robison 1982). First, the axioms underlying the EU hypothesis must be valid. Second, the preference measure assigned to outcomes must accurately reflect the preference orderings of the individual. Third, the choice set must be described accurately; that is, states of nature and their associated probabilities must correspond to subjective beliefs held by the decision-making household.

and p (θ_i) denotes the probability of occurrence for the i^{th} state of nature[6]. The above formulation of expected utility assumes that consumption is the relevant argument of utility.

In many situations, decision-making households may be faced with alternatives that are characterized by multiple attributes. For example, a single attribute (e.g., income) may be considered in multiple time periods, or multiple attributes (e.g., leisure, debt) may be relevant within a single time period. While "standard" EU theory is defined for a single attribute, it may be generalized to multiple attributes. In a case of multiple sectors, households may view the sectors as unique in terms of risk preferences. Multiattribute utility, U, may be depicted as a function of the individual attribute measures x_i (Hardaker *et al* 1997).

(2.2) $U = U(x_1, x_2, .., x_n)$

Assuming that the axioms of EU theory hold for the multiattribute preferences, EU theory is also appropriate for multiple attribute decision-making under risk. The overall expected utility of an option is based on the values assigned to the different attributes. The rational firm is assumed to choose the option with the highest overall (cumulative) value or expected utility. If further assumptions are made concerning the relationship between preferences for various attributes, more can be said about the form of the

6 Departures from linearity in probabilities have led several researchers to generalize the EU model by positing nonlinear functional forms for the individual preference function (Machina 1987). Functional forms of these standard models allow for the modelling of preferences which are more general than those allowed by the expected utility hypothesis (Machina 1987).

multiattribute utility function. For example, the existence of preferential and utility independence[7] implies that a multiattribute utility function can be generalized as:

(2.3) $U(x_1,..,x_n) = U\{u_1(x_1), u_2(x_2),.., u_n(x_n)\}$

In this case, the expected utility for a set of attributes can be derived in stages: that is, at first individually and then combined into a total utility value. The quasi-separable utility function is a more practical variant of the general multiattribute utility function (i.e., equation 2.3) in terms of empirical estimation. If the attribute utility functions $u_i(x_i)$ are scaled from zero to one, and if U is also scaled from zero to one, the function U is either of the additive[8] form:

(2.4) $U(x_1, x_2,.., x_n) = \sum_i \kappa_i u_i(x_i) \qquad (for\ i = 1,2,..,n)$

or of the multiplicative form:

(2.5) $U(x_1, x_2,.., x_n) = \{\prod_i K\kappa_i u_i(x_i) + 1)\}/K \qquad (for\ i = 1,2,..,n)$

where κ_i is a scaling factor between zero and one for $u_i(x_i)$ and K is a dependent scaling factor, the value of which depends on the values κ_i (Hardaker *et al* 1997). Strong separability of utility functions occurs when preferences are pertinent on an element-by-element basis $\{\{1\}, \{2\},\ldots,\{m\}\}$. In this case the utility function is equivalent to an additive utility function $U(x_1) = U(\sum_{i=1}^{m} u_i(x_i))$ where the u_i depend only on individual

7 An attribute X is said to be *preferentially independent* of another attribute Y if preferences for levels of attribute X do not depend on the level of attribute Y. Attribute X is *utility independent* of attribute Y if preferences for uncertain choices (such as lotteries) involving different levels of attribute X do not depend on the level of Y (Hardaker *et al* 1997).
8 Additivity is a special case of separability (Henderson and Quandt 1980).

components of x_i (Luenberger 1995).

Under the assumption that all attribute utility functions $u_i(x_i)$ are linear, $u_i(x_i) = x_i$, the total utility function U is a simple weighted sum of attribute measures (Hardaker *et al* 1997); that is:

(2.6) $U(x_1, x_2, .., x_n) = \sum_i \delta_i x_i$

where δ_i are attribute weights. A general additive utility function that allows for nonlinearity in attribute utilities is of the form:

(2.7) $U(x_1, x_2, .., x_n) = \sum_i \delta_i u_i(x_i)$

where u_i is a function of the attribute measure x_i corresponding to i^{th} attribute and δ_i are attribute weights, usually scaled to sum to 1.0 (Hardaker *et al* 1997). An additive utility function has the property that all cross partials equal zero, that is, $\partial^2 U/\partial x_i/\partial x_j = 0$ for all $i \neq j$, and the regular strict quasi-concavity condition $U_{11}U_2^2 + U_{22}U_1^2 < 0$ in the two-variable case (Henderson and Quandt 1980). However, in many cases, preferences for individual attributes are not independent of one another (Jeffrey and Eidman 1991). Thus additive utility, while analytically convenient[9], is likely to be inappropriate in many cases (Jeffrey and Eidman 1991).

9 There are few alternatives to consider in place of the additive form since the multiplicative form is difficult to estimate empirically.

Some researchers have noted violations of EU model assumptions (Buschena and Zilberman 1994; Schoemaker 1982; Tversky and Kahneman 1981; Mosteller and Nogee 1951). There has been experimental evidence of systematic violations of axioms underlying expected utility theory (Schoemaker 1982). The EU model represents rational choices and does not take into account the impacts of anxieties and worries associated with random outcomes or choices, or the effort and expertise needed for optimal selection (Buschena and Zilberman 1994). The EU model assumes that agents can and will completely optimize their choices, regardless of the importance and difficulty of the decision (Buschena and Zilberman 1994). Despite the experimental evidence of systematic violations of expected utility theory, however, it remains the dominant approach to the economic analysis of choice under uncertainty (Peterson 2002).

2.2.2 Risk Preferences

Risk preferences, or attitudes toward risk, are important because they may influence behaviour in the presence of risk. Risk attitudes have been identified as an important parameter influencing production and consumption decisions (Binswanger 1980; Hazell 1982).

There are three broad categories of risk attitudes: risk averse, risk neutral and risk loving. A decision-making household is risk averse if he/she will not bet when offered an actuarially fair gamble (Nicholson 1995; Katz and Rosen 1994). The risk averse decision-making household rejects a fair bet because of the uncertainties created by it. Risk aversion is characterized by decreasing marginal utility of wealth and results in individuals being willing to pay a positive amount in order to avoid taking risks. A risk neutral decision-making household is indifferent among alternatives with the same expected value (Katz and Rosen 1994). As long as the two outcomes have the same expected value, the decision-making household does not care which one he/she receives, regardless of whether one outcome is more uncertain than the other. A risk loving decision-making household prefers an uncertain prospect with a particular expected value to a certainty with the same expected value (Katz and Rosen 1994). The risk loving decision-making household prefers a gamble with a potentially high pay-off over a sure thing.

A decision-making household's attitude towards risk can be inferred from the shape of his/her utility function. A linear utility function implies risk neutrality, a function concave to the origin implies risk aversion, and a convex function implies a risk preferring attitude (Barry 1984). A concave utility function has the property that marginal utility decreases as the level of the pay-off is increased. The more concave the utility function is, the more risk averse the decision-making household. The relationship between the certainty equivalent (CE) and the expected monetary value (EMV) for a risk alternative can also be used to classify risk attitudes[10]. For a risk averse individual, the CE of a risky investment is always less than its EMV. For a risk loving decision-making

10 The certainty equivalent is the amount exchanged with certainty that makes the decision-making household indifferent between this exchange and some particular risky prospect. The expected monetary value is the wealth (W) that could be expected on average, given two possible outcomes W_1 and W_2 with associated probabilities p_1 and p_2 respectively. This value is also sometimes called the actuarial value of W_1 and W_2 taken jointly, that is, $EMV = p_1*W_1 + p_2*W_2$. (Ellis 1988).

household, the CE is always greater than the EMV. Equality of the CE and the EMV implies risk neutrality.

The difference between the EMV and the CE is a risk premium, RP, which represents the amount that a risk averse individual would be willing to pay, in monetary terms, to avoid the risky action (Barry 1984). The risk premium is determined by the bending rate (slope) of the utility function. As the degree of concavity for the utility function increases, so does the risk premium.

The absolute risk aversion function is a more commonly used measure of risk attitudes (Robison and Barry 1987). Arrow (1965) and Pratt (1964) suggested measuring an individual's risk aversion by calculating the ratio of the second derivative of the utility function of wealth to the first derivative. The resulting coefficient of absolute risk aversion, $r_a(W)$, is defined as:

(2.8) $r_a(W) = -U''(W)/U'(W)$

The coefficient of absolute risk aversion is positive for risk aversion and higher positive values represent greater levels of risk aversion. This measure is consistent with the risk premium in that both are determined by the degree of concavity (i.e. "bending") in the utility function.

2.2.3 Expected Utility in a Decision-making Framework

This section presents an application of expected utility in a household model framework. Under conditions of risk and uncertainty, decision-making households are assumed to optimize expected utility subject to a set of constraints. The theory of expected utility can be placed in the context of solving a decision-making household's problem. Arguments of utility can be in the form of measures such as wealth, profit, expected output, leisure, or consumption goods. The nature of the constraints depends on the type of model under consideration. In the case of a production model, the constraints relate to limited resources such as land, labour and capital availability, and the type of available production technology. In the case of a household model, the set of constraints includes the above subset of production-related constraints plus additional budget and household time related constraints (Strauss 1986). A constrained utility maximization model with consumption as the performance measure is presented below. The household maximizes utility derived from consumption of goods subject to budget, time and production constraints.

$$(2.9) \quad Max\ E(U) = pU(x)$$
$$subject\ to$$
$$Ax \le d$$
$$and\ \ x \ge 0$$

where E(U) is expected utility, x is a vector of nonnegative 'activity levels' or decision variables such as consumption goods (purchased or home produced), p is a vector of state probabilities, U(x) is a vector of utility values for the various x's (i.e., based on the state of nature), A is a matrix of technical coefficients and d is a vector of resource stocks. The vector of state probabilities (p) incorporates risk into the optimization model.

2.2.4 Agricultural Household Models in General

This section provides a review of household models that have been used in an agricultural setting. The manner in which agricultural households respond to interventions is a critical factor in determining the relative merits of alternative policies (Singh *et al* 1986). Agricultural household models are designed to capture the microeconomic behaviour of agricultural households and help inform policy makers of possible effects of different interventions. By integrating production and consumption decisions, agricultural household models provide an appropriate framework for predicting micro-level consequences of some targeted agricultural policies. Agricultural household models provide insights into three broad areas of interest to policymakers: the welfare or real incomes of agricultural households; the spill-over effects of agricultural policies onto the rural non-agricultural economy; and, at a more aggregate level, the interaction between agricultural policy and international trade or fiscal policy (Singh *et al* 1986). The usefulness of household models as a policy tool is a function of, among other things, the comprehensiveness of available data and the quality of behavioural assumptions used in the modelling process.

The basic concept behind household models is that the household allocates time and other resources to produce commodities. Some of these goods are sold in "the market" while others are consumed at home[11]. For some of these goods, no markets exist (Strauss and Duncan 1995). Agricultural households purchase some inputs (e.g., fertiliser) and

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11 Goods and services produced for consumption within the household rather than for market exchange are referred to in the neoclassical literature as Z-goods (Ellis 1988). These include activities such as child care, food preparation and processing.

provide others from their own resources (e.g., family labour). The agricultural household is thus characterized by partial integration into markets. The agricultural household is both a producer and consumer and forms the basic unit of analysis in agricultural household models.

The general agricultural household model provides a framework for generating predictions about the responses of agricultural households to changes in domestic variables (e.g., family size and structure) and market variables (e.g., output prices, input prices, wage rates, and technology). The standard formulation in the agricultural household literature is to assume that the households maximize utility allowing for substitution between consumption and leisure (Singh *et al* 1986).

The existence of complete and competitive markets implies a separation of the consumption (labour supply) and production (labour demand) decisions for the farm household (Benjamin 1992). This separation implies that profits are maximized independently of the utility of consumption. With separability of production and consumption, a household behaves as if it maximizes profits for its farming operation subject to its production constraints and then maximizes utility in consumption subject to its full income[12] and time constraints (Strauss 1986). Separability implies that households are price takers for all commodities. The amount of a commodity to be produced can therefore be assessed independently of the amount to be consumed since

12 By definition, full income includes farm profit. The household has the option of using income earned from farming, off-farm work and remittances to buy food from the market. Production constraints limit the amount of farm output, and therefore farm profit received by the household.

the difference can be purchased from the market. de Janvry *et al* (1991) note that most household models developed have postulated the existence of perfect markets for the goods that are both produced and consumed by the household, thus implying recursiveness between production and consumption (e.g. Lau *et al* 1978; Ahn *et al* 1981). Nonseparability arises from imperfect market conditions, costly information, risk, financial constraints and dynamics (Coyle 1994). de Janvry *et al* (1991) contend that markets for smallholder agricultural households exist in general, but selectively fail for particular households thus making the commodity nontradable for those households. Nonseparation has also been attributed to commodity heterogeneity thus leading to differences between sales and purchase prices (Singh *et al* 1986). Nonseparability affects empirical farm household modelling in two ways: it changes the comparative statics, and it renders statistically inconsistent the usual demand-and-supply parameter estimates (Singh *et al* 1986). de Janvry *et al* (1991) present results of a model of peasant household behaviour under various conditions of market failure for labour and food. Omamo (1998) presented a nonseparable model of smallholder farmers in Kenya that investigated the effect of transport costs on smallholder cropping choices. It is likely that at least some of these conditions exist for the household scenarios in the developing country setting considered in this study.

Given the likely existence of imperfect market conditions for the households under consideration in this study, optimal responses under risk are best investigated within a nonseparable model framework. Nonseparable household models are more relevant given that smallholder producers operate in environments characterized by risk in production and marketing. The presence of risk implies that household production decisions are made without perfect information about future product prices and/or weather conditions. Assuming that consumption decisions are made after output prices and weather are observed, the presence of risk entails that consumer prices will be a function of realised output (Coyle 1994). This situation would imply that production and consumption decisions are not separable (Coyle 1994). Thus smallholder households have to make joint production and consumption decisions.

The literature reviewed on household models does not explicitly address the complexities pertaining to difficulties encountered in data collection and analysis in smallholder agriculture. The extent to which limited data impact on the empirical modelling aspects has not been clearly highlighted. Given the sensitivity pertaining to the collection of production and income data, for example, it is possible that the quality of results obtained largely hinges on the reliability of data collected. Further the extent to which the diversity of different units of measure has on the quality of data collected has not been highlighted. The valuation of production, consumption, sales and purchases is an important aspect of this study. The literature reviewed does not contain evidence of cases where different prices have been used for production, consumption, sales and purchases in an environment characterized by thin markets and risk. This study makes a contribution to some of the knowledge gaps identified above by providing some empirical approaches that were used in addressing some of the issues identified.

2.2.4.1 Nonseparable Static Agricultural Household Model Incorporating Risk

The generalized household model presented above may be used to model the behaviour of smallholder agricultural producers. Early household models (e.g. Chayanov 1926; Low 1986) ignored risk and focused mainly on single farm outputs on the production side (Singh and Janakiram 1986).

The agricultural household faces market risk in the form of uncertain changes in input and output prices. Production risk is present in the form of unpredictable changes in weather leading to variability in the attained level of output. Thus risk can be introduced into the agricultural household model through incorporation of random variables that capture unpredictable changes in prices and/or output. A model depicting price and output risk is presented below[13]. The household, a price-taker in the goods and factor markets, faces the following expected utility maximization problem:

(2.10) $\underset{X}{Max} J = E[U(c,g,l)]$

where E is the expectation operator and U(.) is the household's von Neumann-Morgenstern multiattribute utility function which is assumed to be quasi-concave with positive partial derivatives. The household consumes m farm produced agricultural commodities $c = (c_1,..,c_m)$, n market-purchased goods $g = (g_1,..,g_n)$ and leisure, *l*. The set of choice variables is represented by $X = (c,g,l)$. On the consumption side, utility is maximized subject to a budget constraint:

(2.11) $\tilde{Y} = PX$

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13 The model is adapted from Saha (1994).

where $\widetilde{Y}$ [14] is full household income, $P = (P_c, P_g, P_l)$ where $\widetilde{P}_c$ is a vector of random prices of own farm produce consumed by the household, P_g is price of market purchased goods consumed by the household and P_l is the rural wage rate[15]. The assumption here is that farm product prices are risky while the prices of market purchased goods are not[16]. Full income for an agricultural household equals the value of its time endowment, plus the value of the household's production less the value of variable inputs required for production of outputs, plus any nonwage, nonhousehold production income such as remittances (e.g., cash sent by urban workers for use by resident farm household members) (Strauss 1986):

(2.12) $\widetilde{Y} = \widetilde{\pi} + P_l F + I$

where $\widetilde{\pi}$ is profit derived from farming operations, F is the family's total labour supply (on-farm plus off-farm family labour time) and I is exogenous income such as remittances received. Farm profit is derived as follows:

(2.13) $\widetilde{\pi} = \widetilde{P}_c \widetilde{q} - P_V V - P_l L$

where $\widetilde{q}$ is a vector of farm output[17], V is a vector of non-labour farm inputs, L is total

14 The tildes (~) denote risk or randomness in the respective variable.
15 In this model it is assumed that the value of leisure is equal to a common wage rate for family labour use on-farm and off-farm. The implicit assumption is that on-farm family labour and off-farm family labour are perfect substitutes. This greatly simplifies the model. The reality is that the opportunity cost of time could be different on-farm and off-farm. Market imperfections leading to hiring-in or off-farm employment constraints, or differing efficiencies of family and hired labour are commonly suggested as sources of nonseparability (Benjamin 1992). The model attributes nonseparability to price and output risk only.
16 In reality, households may face market risk with respect to both agricultural and non-agricultural purchased goods.
17 The output could typically be both a food and cash crop. This distinction is implicit in the above set of equations.

labour[18] (family plus hired) used in farm production and P_V is a vector of non-labour input prices. The household produces agricultural commodities according to a well-behaved production function:

(2.14) $\tilde{q} = f(V, L)\tilde{\varepsilon}$

where f(.) is a twice continuously differentiable function that is concave in V and L, and $\tilde{\varepsilon}$ is the random output coefficient which is distributed with a mean of one and a finite variance. The household has a time constraint of the form:

(2.15) $T = F + l$

where T denotes the household's total time endowment. Saha (1994) imposes the following structure to add stochastic elements to output and price:

(2.16) $\tilde{\varepsilon} = \theta + \phi\tilde{e}_1$

(2.17) $\tilde{P}_c = \overline{P}_c + \gamma\tilde{e}_2$

where $E[\tilde{e}_1] = E[\tilde{e}_2] = 0$. Given this output and price structure, the budget constraint, (i.e. equation 2.11), can be formulated as:

(2.18) $$\begin{aligned}\tilde{Y} &= \tilde{P}_c c + P_g g + P_l l \\ &= (\overline{P}_c + \gamma\tilde{e}_2)c + P_g g + P_l l \\ &= \overline{P}_c c + \tilde{R}_2(.) + P_g g + P_l l\end{aligned}$$

where $\tilde{R}_2(.) = \gamma\tilde{e}_2 c$. Constraints given by equations 2.12 to 2.15 can be collapsed to a single constraint:

(2.19) $$\begin{aligned}\tilde{Y} &= \tilde{Z} + I \\ &= \overline{P}_c\theta f(V, L) - P_l(L - F) - P_V V + \tilde{R}_1(.) + I\end{aligned}$$

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18 By valuing family farm labour and hired labour at the same wage rate, the implicit assumption is that the two labour inputs are perfect substitutes.

where $\widetilde{Z}$ is the household's expected income and $\widetilde{R}_1(.) = \overline{P}_c\phi\theta f(.)\widetilde{e}_1 + \gamma\theta f(.)\widetilde{e}_2 + \phi\gamma f(.)\widetilde{e}_1\widetilde{e}_2$ is stochastic.

Thus the optimization problem is set up as follows:

$$\begin{aligned}(2.20)\quad L(c,g,l,\lambda) &= E[U(c,g,l)] + \lambda(\overline{P}_c\theta f(V,L) - P_l(L-F) - P_V V + \widetilde{R}_1(.) + I - \overline{P}_c c - \widetilde{R}_2(.) - P_g g - P_l l) \\ &= E[U(c,g,l)] + \lambda(\overline{P}_c(\theta f(V,L) - c) - P_l(L-F) - P_V V + \widetilde{R}(.) + I - P_g g - P_l l)\end{aligned}$$

where $\widetilde{R}(.) = \overline{P}_c\phi\theta f(.)\widetilde{e}_1 + \gamma\theta f(.)\widetilde{e}_2 + \phi\gamma f(.)\widetilde{e}_1\widetilde{e}_2 - c\gamma\widetilde{e}_2$ is stochastic and λ is a Lagrangian multiplier.

2.2.4.2 Other Models Incorporating Risk

This section provides a brief review of how risk has been incorporated in previous studies and also highlights how household models have been used empirically. Hedden-Dunkhorst (1997) applied the following objective function to a quadratic risk programming model in estimating risk aversion of smallholder producers in Zimbabwe semi-arid areas:

$$\begin{aligned}(2.21)\quad MaxU &= \sum i'X - \Phi(X'\Omega X)^{1/2} \\ &\text{subject to } Ax \le b \\ &\qquad x \ge 0\end{aligned}$$

where U is utility, X is a vector of activity levels, i' represents a vector of mean gross margins and A is a matrix of resource requirements or technical coefficients. The vector of fixed resources and other restrictions is given by b while Φ is a risk-aversion coefficient. The variance-covariance matrix of activity gross margins is represented by Ω. Risk was defined as income variability and results of the study suggested that risk aversion coefficients estimated for different household types were positive.

Wolgin (1975) emphasized the importance of incorporating risk into the modelling of smallholder agriculture. The study was based on the premise that risk was an important consideration such that the farmer maximized expected utility rather than expected income. Risk was incorporated using expected crop output, variance of total income and covariance of income between crops. Under certain assumptions (i.e., those necessary for Expected-Variance analysis) maximizing expected utility involves only the first two moments of the distribution of income (Y). Given this scenario, the following relationship holds (Wolgin 1975):

$$(2.22) \quad Max\ E(U(Y)) \Leftrightarrow MaxU\ (Y_e, \sigma_y^2)$$
$$where\ \partial U / \partial Y > 0\ and\ \partial^2 U / \partial Y^2 < 0$$

where $\Leftrightarrow$ implies is equivalent to, and the right hand side arguments are expected income (Y_e) and the variance of total income (σ_y^2), respectively.

Roe and Graham-Tomasi (1986) presented a nonseparable dynamic version of the agricultural household model that incorporated production risk, but not price risk. The objective of their study was to determine the impact of yield risk and the household's risk preferences on its production and consumption decisions. The additive form of the quasi-separable utility function was adopted given that household decisions were made to optimize multiple objectives.

The household models described above can be solved empirically using econometric or mathematical programming methods. The choice of method is partly a function of the purpose of the study, data and software availability and ease of estimation. In this study, mathematical programming approaches are adopted to solve agricultural household models of smallholder agricultural producers in Zimbabwe. The next section provides a description of the quantitative model that was used in this study.

2.2.5 Utility-Efficient Programming Household Model

This section presents the analytical method to be used in this study for estimating empirical models of smallholder agricultural producers. Risk programming models are used extensively to examine the impact of risk on firm production decisions. The model is adapted for use in examining the impact of risk on household production and consumption decisions. The Utility Efficient (UE) programming model is selected as the behavioural model in this study, by virtue of its desirable properties. The UE programming model has several advantages. First, the UE programming model is flexible in that a number of types of risk preferences can be modelled. The UE programming model can be applied to situations where the rational firm is not necessarily risk averse and even where the utility function is not known. Second, the degree of risk aversion can be limited to a plausible range. Third, it has the advantage of allowing the available data to indicate the nature of the multivariate distribution, while also allowing for a degree of subjectivity if appropriate, for example by assigning subjective probabilities to states of nature. Finally, the technique can be used with available solution algorithms (Patten *et al* 1988). The literature reviewed does not contain evidence of the use of the UE programming model in developing country settings similar to the Zimbabwean case.

The objective function of the UE programming model is the parametric sum[19] of two parts of the utility function (Patten *et al* 1988). The general form of separable utility functions to which the UE programming model objective function belongs is:

$$(2.23)\quad U = G(C) + \lambda H(C)$$

where C is consumption and G and H are appropriately selected functions of C. G and H are polynomials with H being of second order or higher (Patten *et al* 1988). The degree of risk aversion being modelled varies with the parameter λ. The general structure of the UE model is as follows:

$$(2.24)\quad \underset{x}{Max}\, E(U) = \sum_{k} p_k [G(C_k) + \lambda H(C_k)]$$

$$\begin{aligned} &\textit{subject to} \\ &\quad C_k = c_k{}'x \textit{ for } k = 1,\ldots,K \\ &\quad Ax \le d \\ &\textit{and } x \ge 0 \end{aligned}$$

where λ is a non-negative risk aversion parameter, p_k is the probability of state k, G and H are two parts of the utility function U, C_k is total consumption for state k, c_k is the activity consumption vector for state k (or technical coefficients of consumption for state k), x is the vector of activity levels, A is the matrix of input-output coefficients, and d is the vector of right-hand side coefficients. Uncertainty in activity consumption is captured through state-specific values for c_k. Variation in parameter λ can be interpreted as variation in risk preference (Hardaker *et al* 1991). In this model, risk is assumed to be captured completely in the objective function.

19 The sum varies with changes in values of parameters such as λ.

In household models, a state of nature typically corresponds to a particular type of year such as a wet versus a dry year, or a high-price versus a low-price year (Hazell and Norton 1986). The relevant constraints relate to any 'typical' household constraints such as those considered in making production and consumption decisions.

The objective function for the UE programming model (i.e., the utility function) may take on a number of specific forms. For example, the objective function can be of the sumex form:

(2.25) $U = -\exp(-aC) - \lambda \exp(-bC), a, b, \lambda \geq 0$

The parameter λ is varied using a parametric objective programming algorithm. At each change of basis, corresponding to a particular level of risk aversion, the expected utility maximizing model solution is identified (Patten *et al* 1988). The sumex function has the property that:

(2.26) $r_a = [a^2 \exp(-aC) + \lambda b^2 \exp(-bC)]/[a \exp(-aC) + \lambda b \exp(-bC)]$

where r_a is the coefficient of absolute risk aversion, defined as $-U''/U'$ (Arrow 1965). The degree of risk aversion varies with λ. When $\lambda = 0$, $r_a = a$, whereas when $\lambda \rightarrow \infty$, $r_a = b$ (Patten *et al* 1988). The parameters a and b thus represent lower and upper bounds of the range of r_a. These parameters may be used to limit the range of risk aversion levels under consideration. Therefore, by varying λ, it is possible to model alternative levels of risk aversion to obtain a set of risk efficient solutions. In this study, empirical models of the household incorporating risk are modelled for representative households.

An alternative form of the UE programming model objective function makes use of the negative exponential function of the parametric form (Hardaker *et al* 1991):

(2.27) $U = \exp[-\{(1-\lambda)a + \lambda b\}C]$

This formulation results in a coefficient of absolute risk aversion varying between a when λ is zero and b when λ is 1.0. The approach has the capacity to generate the set of solutions that are stochastically efficient for all decision-making households whose coefficient of risk aversion is in the relevant range (Hardaker *et al* 1997).

The techniques described here consider utility maximization directly by using the household's utility function expressed in the sumex or negative exponential function. The UE programming model can be used to generate optimal production and consumption activity levels for the agricultural household scenarios under consideration in this study. Software incorporating nonlinear algorithms, such as GAMS (Generalized Algebraic Modelling Systems), are capable of solving the UE programming model problem.

2.3 Empirical Methods

One objective of this study is to investigate risk preferences for households. Empirical methods pertaining to the measurement of risk preferences and approaches to modelling leisure in household models of smallholder agricultural households are described in this section.

2.3.1 Empirical Methods of Estimating Risk Preferences

This section describes approaches that can be used to estimate risk preferences of decision-making households. The three major methods for measuring risk preferences are the direct elicitation of utility functions (DEU) method, the experimental method (EM) and observed economic behaviour (OEB) method.

The DEU method involves direct contact with households to elicit their risk attitudes. Utility functions are derived through interview procedures designed to specify points of indifference between certain outcomes and risky options involving hypothetical gains and losses. Hypothetical gambles involving monetary gains and losses are used to yield points in utility-monetary outcome space that can be expressed as a utility function (Barry 1984). Such attempts to elicit individual risk preferences are expensive and time consuming (Hazell 1982).

Experimental methods are based on gaming situations with actual payouts. Respondents are asked to choose between lotteries that differ in payoffs and probabilities or both (Buschena and Zilberman 1994). A commonly used variant of the EM is to use one-shot experiments, thus avoiding learning effects. Another variant of this method involves using extended experiments with actual (real) payoffs thus allowing learning effects. Agents are able to choose between various simple lotteries with multiple plays. The major problem with the experimental approach is that the context of the experiment is typically not representative of the decision problems commonly faced by agents (Young 1979).

The OEB method provides an indirect measure of risk preferences. The method draws inferences about risk attitudes based on the relationship between the actual behaviour of decision-making households and the behaviour predicted from underlying economic behavioural models. The approach compares OEB with respect to factor demand and output supply to behaviour predicted by theoretical (behavioural) models incorporating risk and risk preferences (Young 1979). OEB approaches generally use mathematical programming or econometric procedures for predicting behaviour (Pope 1982). The OEB approach escapes the compelling criticism that the recovered preferences may not be germane to real world decisions (Barry 1984; Young 1979). Adamowicz *et al* (1997) noted that hypothetical questions are difficult to construct and administer in some cultural contexts. Modelling actual behaviour avoids difficulties pertaining to the use of hypothetical questions.

The main shortcoming of the OEB method is that it attributes all deviations from observed behaviour to risk. In reality, many other factors besides risk influence observed behaviour (Barry, 1984). For example, if the specified model omits certain factors constraining decisions, then the degree of risk aversion may be overstated.

The OEB method can be implemented using mathematical programming methods (e.g. Hedden-Dunkhorst 1997) or econometric methods (e.g. Antle 1987, 1989). In mathematical programming approaches, risk aversion coefficients are derived through parameterization techniques applied at various levels of risk aversion. The household's performance as observed is then compared with the performance of the household predicted within a particular behavioural model. It is thus assumed that the model is sufficiently comprehensive so that the risk aversion coefficient, which matches predicted and observed performance of the household, represents the true risk aversion of the household (Hedden-Dunkhorst 1997). The OEB approach is used in this study to estimate risk preferences of smallholder agricultural producers. Observed values of production are compared with predicted values using a mathematical programming based grid search to estimate the risk preferences of representative households.

McCarl and Spreen (1997) present an example of how the risk aversion parameter (λ) can be estimated using the OEB approach. They start with a vector of observed solution variables such as acreages devoted to different cropping enterprises. The next step is to vary λ ($0 \leq \lambda \leq \infty$) in small steps (e.g., 0.25 in the range 0 to 2.5). At each change of basis, corresponding to a particular level of risk aversion, the expected utility maximizing solution is identified. A measure of the difference between the model solution and the observed behaviour is calculated at each change of basis. In the case of crop enterprises, crop acreage difference is measured as the absolute acreage difference between the observed and simulated solutions summed over all crops (Brink and McCarl 1979). Lastly, the value of λ for which the smallest difference is found between the model solution values and observed values is selected to represent the farmer's risk preferences. Thus, one can calculate risk preferences for each individual household by varying the risk parameter in this fashion.

2.3.2 Approaches to Modelling Leisure in Household Models

The literature on agricultural household models presents two major approaches to considering leisure in agricultural households. The first set of studies explicitly considers leisure. Such studies include Strauss (1982, 1984), Lau *et al* (1978), Coyle (1994) and Young and Hamdok (1994). One justification for including leisure is that in communities where significant off-farm income earning opportunities exist, the opportunity cost of leisure is high. As a result, leisure should be included to capture the opportunity cost of alternative time use. This scenario holds in communities where, during the dry season, household members seek seasonal off-farm employment if they have the opportunity. Assuming that this school of thought holds, leisure would need to be explicitly included in household models in order to avoid getting biased estimates.

A second school of thought suggests that leisure need not be incorporated into the analysis of household production. Lobdell and Rempel (1995) argue that leisure can be excluded from household analysis, for two reasons. First, it is argued that in peasant households the typical trade-off is between different types of work activities, or between more or less work effort, rather than between work and leisure *per se*. The other reason is that in a society where significant amounts of time and effort are invested in the maintenance of social relationships, the distinction between work and leisure becomes problematic. Assuming that leisure can be excluded from the analysis, the amount of family labour devoted to farm and off-farm work can be taken as a close proxy to the total stock of family time available to the household.

The first school of thought is consistent with the hypothesis that there is seasonal variation in the demand for labour. It is assumed that during the dry season there is more time available so that household members start seeking off-farm employment. The second school of thought is consistent with the hypothesis that there is little variation in the demand for labour – that leisure time remains somewhat constant, and that relevant tradeoffs are between types of work. The literature reviewed does not contain evidence of any previous studies that have carried out an exercise to assess whether leisure should be explicitly modelled in household models. Given the relevance to the structure of household models, this issue is investigated in the current study.

2.3.3 Empirical Risk Preference Estimation Results From Developing Countries

Empirical estimates of absolute risk aversion measures derived in previous studies are examined in this section. Difficulties in comparing estimates of risk preferences derived from other studies are detailed below. The objective of the review is to present the range of results obtained in previous studies and to highlight issues pertaining to comparisons of risk estimates derived from other studies.

The focus of the review is on studies of smallholder agriculture in developing countries since that is the context within which this study is conducted. It has been noted that farmers' attitudes toward risk depend on many things, ranging from cultural background to psyche (Hamal and Anderson 1982). Raskin and Cochran (1986) state that the Pratt-Arrow measure of absolute risk aversion is well known to be invariant to linear transformations. However, this invariance property applies with respect to transformations of the utility function and not with respect to arbitrary rescalings of the outcome variables (Raskin and Cochran 1986). This makes comparisons of results between studies more difficult.

Table 2.1 provides a summary of measures of absolute risk aversion derived from previous studies by geographic zone. In a study of four semi-arid communal areas located in Matabeleland South (Zimbabwe), Hedden–Dunkhorst (1993) computed risk aversion coefficients based on a quadratic programming model. The study was conducted in 1988 and was based on a field survey of 192 households. Risk was defined as income variability. Quadratic programming, within a utility maximizing framework, was used to identify the relevance of risk in the process of household decision-making. Eight coefficients of absolute risk aversion were computed. The coefficients ranged from 0.58 to –0.06 among the study areas and household groups.

Dillon and Scandizzo (1978) conducted a risk attitude study of small farm owners and sharecroppers in Caninde county in northeast Brazil. The DEU approach was used, but no explicit utility functions were estimated (Young, 1979). Farmers' risk attitudes were appraised via their choices between hypothetical but realistic farm alternatives involving risky versus certain outcomes. The study was carried out within the expected utility framework. The mean values of absolute risk attitude coefficients by type of utility function were as follows: linear (-1.01 to –0.86), quadratic (-0.06 to 0.04) and exponential: (-3.46 to –1.62). For all three utility function models, estimation of their risk attitude coefficient was based on solution of the relationship that the utility of a risky prospect was equal to the utility of its certainty equivalent (Dillon and Scandizzo 1978).

Moscardi and de Janvry (1977) derived attitudes toward risk among peasant farmers in Puebla, Mexico, using an observed behaviour model. An econometric approach was used to estimate the risk aversion parameter K of each household. Since nitrogen was agronomically the most important input for increasing yields in the area and was also the largest component of variable costs, its marginal productivity derived from the farm experiments was used to calculate the risk-aversion parameter K for each farm household. Parameter K was the marginal rate of substitution between expected income and risk and represents an index measure of absolute risk aversion. K could easily be derived for each peasant from knowledge of the production function, the coefficient of variation of yield, product and factor prices, and observed levels of factor use. The results showed a distribution of risk aversion highly skewed toward risk aversion and centred around $K = 1.2$. The estimates of the risk parameter K were used to classify peasant farmers into three groups of low risk ($0 < K < 0.4$), intermediate risk ($0.4 \leq K \leq 1.2$) and high risk ($1.2 < K < 2$).

Antle (1987) investigated the risk attitudes of rice producing farmers from the south central Indian village of Aurepalle using econometric methods. The parameters of the distribution of risk attitudes were estimated using an instrumental variables approach. A mean coefficient of absolute risk aversion of 3.272 was estimated.

Wiens (1976) used a quadratic risk programming model to examine the impact of yield uncertainty on peasant allocation of land among crops and hired factors in North China. Estimates of the absolute risk aversion parameter for large and small farms were 0.0085 and 0.091, respectively.

Bar-Shira *et al* (1997) used an econometric approach to estimate Arrow-Pratt coefficients of small farm owners in Israel. The median and mean values of the coefficients of absolute risk aversion were 0.0000044 and 0.0000045, respectively. It is not clear whether these farms are smallholder farms or large commercial operations.

The above studies present a wide range of estimates of the parameter of risk aversion derived using different approaches and in different time periods and socio-cultural settings. Most of the reviewed studies have used the OEB approach. Despite a wide range of values, these results are consistent in that the values obtained are mainly positive, suggesting a tendency towards risk aversion. This forms a justification for excluding negative values for the coefficient of absolute risk aversion in the models constructed for this study.

Given the wide variability in values of the coefficients of risk aversion obtained for developing country agriculture, there is no consensus on appropriate measures of absolute risk aversion to be used in characterizing developing country agriculture. Therefore, it is difficult to adopt estimates of measures of absolute risk aversion derived from other studies. Even if an adjustment for differences in units were undertaken, there would still be a large variation in the values of the measures of absolute risk aversion. Adjusting risk aversion values of past work is not done in this study. Instead, the study will make use of recovered risk preferences for the sample of agricultural households surveyed.

2.3.4 Multiple Sector Models

Multiple sector studies have mainly typically been based on a comparison of urban and non-urban sectors. Luckert *et al* (2000) constructed a household production model based on the multinomial logistic function to study household resource allocations in response to risks and returns in western Zimbabwe. The study focussed on the following four sectors: agriculture, woodlands (with wood and non-wood sub-sectors), livestock and urban. The literature does not contain multiple sector studies that have assessed whether results of household models differ depending on the number of sectors modelled.

2.3.5 Multiple Risk Parameter Models

Previous studies on risk have typically assumed the existence of a single risk parameter for production models (Hedden-Dunkhorst 1993; Dillon and Scandizzo 1978; Wiens 1976; Antle 1987; Moscardi and de Janvry 1977). A common risk parameter implies an assumption of identical risk preferences for all sectors modelled. However, one might also consider having different risk parameters for different sectors within a model if it is possible that household behaviour is such that they have unique preferences for consumption from different sectors. Unique risk preferences result from the fact that the household derives different marginal utilities of consumption from different sectors. Multiple risk parameters are therefore potentially relevant in understanding the behaviour of households. An incorrect assumption concerning household behaviour would lead to biased estimates.

The implication of using multiple risk parameters is that each sector's utility function has the potential to have a different marginal utility. Thus under a separable multiattribute utility framework, the utility from the first unit consumed of each sector's good is independent of the utility derived from consuming a unit from another sector. The literature reviewed has not shown evidence of any previous studies that have compared results of multiple sector models modelled with single risk parameters with those for multiple sector models with risk parameters that are unique to each sector. This study compares results of household models with single and multiple risk parameters.

2.3.6 Policy Simulations

The representative household model can be used to simulate the impact of alternative policies on the micro-economic behaviour of specific groups of agricultural producers. Policy simulations for developed countries have mainly been based on mathematical programming models for commercial farming enterprises. The literature reviewed showed that scant attention has been paid to the use of policy simulations within a household model framework in developing countries. In this study, a mathematical programming model is used to assess the effect of alternative policies pertaining to credit on household resource allocation for smallholder agricultural producers. Despite the fact that lack of credit has been shown to be a key constraint to agricultural development

(Mortimore 1998), previous studies have not applied policy simulations based on credit availability.

2.4 Issues Addressed in this Study

This section describes the issues arising out of the literature review that will be analyzed in this study. These issues include investigating whether leisure should be explicitly modelled, estimating risk preferences, investigating whether results of partial sector models are improved by increasing the number of sectors being modelled, investigating whether results of household models are improved by increasing the number of risk parameters being modelled, and assessing the potential use of household models in policy simulations.

2.4.1 Modelling Leisure in Household Models of Smallholder Producers

As noted earlier, there is debate on whether leisure should be explicitly modelled in household models of smallholder agricultural producers. As a contribution to the debate on whether leisure should be explicitly modelled in household models, this study presents results of an investigation that inquires into the seasonality in the opportunity costs of labour.

2.4.2 Recovering Risk Preferences

In order to address the impact of risk on household decisions, values of risk aversion measures are required. Few studies have calculated risk preferences in developing countries. In this study, mathematical risk programming techniques are used in conjunction with the Observed Economic Behaviour (OEB) approach to recover risk parameters for representative households. The OEB method is chosen for this study given that the study is based on household data that were previously collected; that is, data arising from observed behaviour of households.

2.4.3 Comparison of Results of Models with Alternative Sectors

There has been a lack of empirical work in previous studies to assess how much of a difference the number of sectors modelled makes to results of household models. In general, multiple sector modelling may be important for increased accuracy in modelling and is also realistic since households have to make decisions between competing sectors. On the other hand, multiple sector modelling is more demanding and may lead to a lower degree of resolution as analysis effects are spread over more sectors. One objective of the study is to investigate whether results of partial sector models are improved by increasing the number of sectors being modelled. Such a comparison will provide an indication as to whether results of household models differ depending on the number of sectors being modelled. An objective of the study is to assess the extent to which the number of sectors modelled impacts on results of household models with different numbers of sectors.

2.4.4 Comparison of Results of Models with Alternative Risk Preference Parameters

Previous studies have used single risk parameters within a multiattribute utility framework. This study investigates whether results of household models are improved by increasing the number of risk parameters being modelled. This study will try to establish whether decision-making households display differing levels of risk aversion in making decisions for different sectors. Results for models with a single risk parameter for all sectors modelled will be compared with those for models with unique risk parameters for each sector modelled.

2.4.5 Policy Simulations Based on Credit Availability

As noted earlier, one objective of this study is to simulate the effects of selected policy changes on households. Apart from Luckert *et al* (2000), the literature reviewed does not contain evidence of multi-sector studies incorporating risk that have used policy simulations within a household modelling framework in developing countries. Thus, there has been a lack of attention on how household models can be used in policy analysis. It has been noted that financial capital in the form of cash is severely constrained in smallholder agriculture (Mortimore 1998). The policy simulations investigated in this study are therefore based on the availability of credit in the form of different levels of a cash loan. This study will simulate the effect of different levels of cash loans on resource allocation by households of differing wealth status. A demonstration of the use of policy simulations of this nature will hopefully provide donor agencies and other development related groups with a tool that can be used to assess whether development aid ultimately benefits the intended household groups.

Table 2.1 Summary of Empirical Estimates of Absolute Risk Aversion

Source	**Geographic Zone**	**Method**	**Absolute Risk Aversion Estimates**
Hedden–Dunkhorst (1993)	Africa	OEB	Absolute risk attitude coefficients ranged from 0.58 to –0.06.
Dillon and Scandizzo (1978)	South America	DEU	Means of estimated absolute risk attitude coefficients ranged from 0.04 to -3.46. The estimates were based on linear, quadratic and exponential utility functions. For all three utility function models, estimation of their risk attitude coefficient was based on solution of the relationship that the utility of a risky prospect was equal to the utility of its certainty equivalent.
Moscardi and de Janvry (1977)	South America	OEB	The distribution of risk aversion was centred around the risk aversion parameter, K, where K=1.12. K was the marginal rate of substitution between net income and risk, i.e., the measure of risk aversion suggested by Magnusson (1969). K was a function of the peasant household socio-economic characteristics.
Antle (1987)	Asia	OEB	Mean coefficient of absolute risk aversion obtained was 3.272
Wiens (1976)	Asia	OEB	Estimates of the absolute risk aversion parameter λ for large and small farms were 0.0085 and 0.091, respectively.
Bar-Shira *et al* (1997)	Middle East	OEB	The median and mean coefficients of absolute risk aversion were 0.0000044 and 0.0000045, respectively.

Notes: OEB = Observed Economic Behaviour
DEU = Direct Elicitation of Utility

CHAPTER 3

Model Development

3.1 Introduction

This chapter presents a description of the structure of empirical household models solved in this study.

3.2 General Objective Functions for Smallholder Agricultural Producers

This section presents a set of alternative objective functions for smallholder agricultural households. The models presented in this study capture static behaviour in an otherwise dynamic framework since households face multi-period decisions that are influenced by risk. Two models of the agricultural household are presented that incorporate leisure implicitly. Explicit treatment of leisure is excluded from the empirical models of smallholder agricultural producers based on empirical results presented in Chapter 5.

The models that follow are based on utility of consumption. This approach is taken because the households analysed in this study are semi-subsistence farmers who grow crops mainly for own consumption with few sales. Income generated from crop sales is generally used to buy food.

The two specifications of household models and the further investigations into the role of leisure are used to assess the impact of risk and risk preferences in determining optimal production and consumption patterns. The formulations are based on multiple sectors that can be modelled using either single or multiple attribute utility functions. In the single attribute utility function, the household's utility maximization problem is modelled as:

$$(3.1)\quad E(U) = \sum_k p_k U(\sum_j c_{jk})$$

where p_k is the probability of occurrence of state k and c_{jk} is consumption of output from sector j in state k. The single attribute in this case is aggregate consumption for all sectors being modelled. Risk preferences in the single attribute utility function are incorporated into the objective function using a single risk parameter.

The formulation of the second objective function is based on a multiattribute utility function having sector-specific consumption as attributes of the utility function. One potential advantage of such a specification is that the impact of risk and risk preferences can be investigated in a multiple sector framework, thus allowing for situations where risk preferences may be sector specific. This specification also allows for an investigation of impacts of modelling multiple sectors. The household derives utility from consuming goods and services obtained directly or indirectly from each of the individual sectors. The household's utility function is of the form:

$$(3.2)\quad E(U) = \sum_k p_k \sum_j U_j(c_{jk})$$

where all notation is defined as above, and U_j is the sector-specific utility function. The above general formulations are adapted for specific versions of the empirical models of smallholder agricultural producers.

3.3 Structure of Empirical Household Models

The Utility Efficient (UE) programming model is adopted for this study by virtue of its desirable characteristics as highlighted in the previous chapter. The sumex form of the objective function of the UE programming model was selected for this study[20]. Utility maximization entails having the farmer's utility function expressed as the objective function of the UE programming model (i.e., equation 2.24). The empirical specifications of the UE programming model used in this study are presented and discussed below. These specifications differ in terms of the objective function used; that is, whether activities in alternative sectors are included.

This study utilizes two types of agricultural household models. The first type of model is agriculture based and consists of dryland agriculture and gardens sectors and is termed the double sector household model. The second type of model is composed of three sectors; dryland agriculture, gardens, and woodlands. It is referred to as the tri-sector household model. The double sector model is solved with either one or two parameters of risk aversion while the tri-sector model is solved with either one or three parameters of

20 Patten *et al* (1988) suggested that any suitable separable utility function could be used in the programming formulation. A number of these functions have the characteristic of decreasing absolute risk aversion. The choice of the sumex function was therefore somewhat arbitrary.

risk aversion. In the case where one risk parameter is considered, overall consumption is the single attribute of the utility function. The additive multiattribute utility function is adopted for scenarios where *n* consumption attributes are treated as separate attributes within one time period. In these cases, sector-specific consumption levels are the attributes under consideration.

The rational household is expected to maximize expected utility subject to land, time, labour, income and production constraints. The additive utility function is consistent with the separable structure of the UE programming model adopted for empirical analysis. Since leisure is excluded from the utility function, the amount of family labour devoted to farm and off-farm work is a proxy of the total stock of family time available within the household.

Iterative solves were used in this study in order to vary the value of the parameter of risk aversion. The value of the parameter of risk aversion was programmed to increase by a predetermined constant value in the grid search for the value of the parameter of risk aversion that best represented the risk preferences of a particular representative household or wealth quartile.

3.3.1 Double Sector Household Model with a Single Risk Parameter

The objective function, model activities, parameters and constraints for the double sector model are presented below.

3.3.1.1 Model Structure

The objective function for the double sector model with a single risk parameter represents the expected utility of consumption of commodities from dryland agriculture and gardens sectors. The household's assumed utility maximization problem is shown below.

$$(3.3)\quad Maximize: \ \sum_k (p_k * (-EXP(a * \sum_j (P_{cjk} * CON_{jk})) - \lambda * (-EXP(b * \sum_j (P_{cjk} * CON_{jk})))))$$

$subject\ to:$

$$(3.3-1)\quad PROD_j \le END_j \ \forall j$$

$$(3.3-2)\quad PRKG_{jk} = YLD_{jk} * PROD_j \ \forall j,k$$

$$(3.3-3)\quad \sum_j (l_j * PROD_j) - HL \le F$$

$$(3.3-4)\quad \sum_j (d_j * PROD_j) - DL \le D$$

$$(3.3-5)\quad CON_{jk} + SELL_{jk} \le (YLD_{jk} * PROD_j) + BUY_{jk} \quad \forall j,k$$

$$(3.3-6)\quad \sum_j (VC_j * PROD_j) + (w_H * HL) + (P_{DL} * DL) + \sum_j (P_{bjk} * BUY_{jk}) + DOMEXP_k \le \sum_j (P_{sjk} * SELL_{jk}) \quad \forall k$$

$$(3.3-7)\quad VALUE \le \sum_j (P_{sjk} * YLD_{jk}) * PROD_j$$

$$(3.3-8)\quad non-negativity$$

$given\ that$ sec$tor\ j = 1\ (gardens), j = 2\ (dryland\ agriculture).$

3.3.1.2 Model Activities

The activities in the model are defined as follows:

$PROD_j$	=	acres of production for sector j
$PRKG_{jk}$	=	production in kilograms for sector j in state of nature k
$SELL_{jk}$	=	quantity of sector j sold in state of nature k in kilograms
BUY_{jk}	=	quantity of sector j bought in state of nature k in kilograms
CON_{jk}	=	quantity of sector j consumed in state of nature k in kilograms
HL	=	hours of hired labour

DL = hours of hired draught animals

VALUE = value of output produced in all sectors

3.3.1.3 Model Parameters

The parameters of the model are defined as follows:

EXP = exponential function

a = lower bound of the coefficient of absolute risk aversion

b = upper bound of the coefficient of absolute risk aversion

λ = risk aversion parameter

p_k = probability of occurrence for state of nature k

P_{cjk} = consumption value per unit quantity of sector j in state of nature k

P_{sjk} = selling price per unit quantity of sector j in state of nature k

P_{bjk} = purchase price per unit quantity of sector j in state of nature k

VC_j = variable cost per acre for sector j (excluding labour)

l_j = labour requirement in hours per acre for sector j

F = hours of family household labour available for use in dryland agriculture and gardens

d_j = draught requirement in hours per acre for sector j

D = hours of family household draught animals available for use in dryland agriculture

YLD_{jk} = yield in kg/acre (or kg/hour for woodlands) for sector j in state of nature k

w_H = wage rate in Z$ (Zimbabwean dollars) per hour paid for hired labour

P_{DL} = draught hire cost in Z$ per hour

END_j = household land base in acres for sector j

$DOMEXP_k$ = value of transfers to the domestic sector in Z$ in state of nature k.

3.3.1.4 Model Constraints

Constraint (3.3-1) states that land used in production, by sector, cannot exceed the household land resource base and there is no substitution of land uses across sectors. There was no evidence of renting land in the survey area. Moreover, there was no evidence of changing land uses between garden and dryland crops. Land available for dryland agriculture and gardens production was therefore fixed. Constraint (3.3-2) states that output produced, by sector and state, is derived as the product of yield and acreage. Constraint (3.3-3) states that labour hours used in production cannot exceed hired labour plus family labour hours allocated to production. The right hand side parameter for the labour constraint represents the stock of family labour available for use in production. Constraint (3.3-4) states that the hours of draught animals used in production cannot exceed the sum of the stock of own draught animal hours plus hours derived from the use of hired draught animals by sector. Constraint (3.3-5) states that the use of any particular commodity (consumption plus sales) cannot exceed availability of that commodity (production plus purchases) by sector and state. Constraint (3.3-6) states that household expenditures cannot exceed household income inflows by state. Constraint (3.3-7) states that the value of output produced is less than or equal to the sum of the value of yield produced and acreage planted. Lastly, constraint (3.3-8) requires non-negativity for all activities.

The set of constraints presented above relate mainly to production. This can be attributed to the nature of data collected for the household livelihoods survey and later availed for this study. Appendix A, Section A1 provides an example of the GAMS version of the double sector model with a single risk parameter.

3.3.2 Double Sector Household Model with Two Risk Parameters

The double sector model with sector specific parameters of risk aversion has the same basic structure as the double sector model with one risk parameter, with minor adjustments. The objective function has two risk parameters (λ_1, λ_2) and two values for the lower and upper bounds for the coefficient of absolute risk aversion (a_1, a_2, b_1,b_2) where 1 and 2 are indices for gardens and dryland agriculture, respectively. Appendix A, Section A2 provides a listing of the changes that are needed in the programming in order for the double sector model with a single risk parameter to accommodate a second risk parameter. The objective function for the double sector model with two parameters of risk aversion is set up as follows:

$$(3.4)\quad Maximize: \sum_k (p_k * (-EXP(a_1 * \sum_1 (P_{c1k} * CON_{1k})) - \lambda_1 * (-EXP(b_1 * \sum_1 (P_{c1k} * CON_{1k})))))$$
$$+ \sum_k (p_k * (-EXP(a_2 * \sum_2 (P_{c2k} * CON_{2k})) - \lambda_2 * (-EXP(b_2 * \sum_2 (P_{c2k} * CON_{2k})))))$$

where all parameters and variables are defined as before.

3.3.3 Tri-Sector Household Model with a Single Risk Parameter

The objective function, model activities, parameters and constraints for the tri-sector model are presented below.

3.3.3.1 Model Structure

The objective function for the tri-sector model with a single risk parameter represents the expected utility of consumption of commodities from dryland agriculture, gardens and woodlands sectors. The household's utility maximization problem is shown below.

$$(3.5)\quad Maximize:\ \sum_k (p_k * (-EXP(a * \sum_j (P_{cjk} * CON_{jk})) - \lambda * (-EXP(b * \sum_j (P_{cjk} * CON_{jk})))))$$

$subject\ to:$

$$(3.5-1)\quad PROD_j \le END_j\ \forall j$$

$$(3.5-2)\quad PRKG_{jk} \equiv YLD_{jk} * PROD_j\ \forall j,k$$

$$(3.5-3)\quad \sum_j (l_j * PROD_j) - HL \le F\quad \forall j = 1,2$$

$$(3.5-4)\quad \sum_j (d_j * PROD_j) - DL \le D$$

$$(3.5-5)\quad CON_{jk} + SELL_{jk} \le (YLD_{jk} * PROD_j) + BUY_{jk}\qquad \forall j,k$$

$$(3.5-6)\quad \sum_j (VC_j * PROD_j) + (w_H * HL) + (P_{DL} * DL) + \sum_j (P_{bjk} * BUY_{jk}) + DOMEXP_k \le \sum_j (P_{sjk} * SELL_{jk})\quad \forall k$$

$$(3.5-7)\quad VALUE \le \sum_j (P_{sjk} * YLD_{jk}) * PROD_j$$

$$(3.5-8)\quad non-negativity$$

$given\ that$ sector $j = 1\ (gardens), j = 2\ (dryland\ agriculture), j = 3\ (woodlands)$.

3.3.3.2 Model Activities

The activities for the tri-sector models are as defined for the double sector model (equation 3.3).

3.3.3.3 Model Parameters

The parameters of the tri-sector models are as defined for the double sector model (equation 3.3).

3.3.3.4 Model Constraints

The constraints set is basically the same as for the double sector models, with a few modifications that are discussed in Section 3.3.6. Appendix A, Section A3 provides the GAMS program of the tri-sector model with a single risk parameter.

3.3.3 Tri-Sector Household Model with Three Risk Parameters

The tri-sector model with sector specific parameters of risk aversion has the same structure as the tri-sector model with one risk parameter with the following adjustments. The objective function has three risk parameters (λ_1, λ_2, λ_3) and three values for the lower and upper bounds of the coefficient of absolute risk aversion (a_1, a_2, a_3, b_1, b_2, b_3) where 1, 2 and 3 are indices for gardens, dryland agriculture and woodlands, respectively. Appendix A, Section A4 provides a listing of programming changes that are needed to enable the tri-sector model with a single risk parameter to accommodate three risk parameters. The objective function for the tri-sector model with three parameters of risk aversion is set up as follows:

$$(3.6)\quad Maximize: \sum_k (p_k * (-EXP(a_1 * \sum_1 (P_{c1k} * CON_{1k})) - \lambda_1 * (-EXP(b_1 * \sum_1 (P_{c1k} * CON_{1k})))))$$
$$+ \sum_k (p_k * (-EXP(a_2 * \sum_2 (P_{c2k} * CON_{2k})) - \lambda_2 * (-EXP(b_2 * \sum_2 (P_{c2k} * CON_{2k})))))$$
$$+ \sum_k (p_k * (-EXP(a_3 * \sum_3 (P_{c3k} * CON_{3k})) - \lambda_3 * (-EXP(b_3 * \sum_3 (P_{c3k} * CON_{3k})))))$$

where the parameters, and variables are as defined before.

3.3.4 Solution Procedures for Models

There are two solution procedures available in GAMS. First, models can be solved using solution procedures that restart from an automatically constructed advanced basis (Brooke *et al* 1998). For iterative solves (or sequential solves), GAMS uses the variable level (solution) values of the first solve as starting point values for the next solve. Model parameters remain the same unless they are reassigned. The implication is that solutions for two adjacent solves are not independent. This approach is the default for GAMS and the default variable starting level is 0, if no finite lower bound has been set, or the lower bound (if it is indeed finite).

Alternatively, models can be solved using a reinitialized basis; that is, solutions from previous solve statements are ignored[21]. In this case, the starting point values for each variable in a new solve statement are either default values or specific target values. The rationale for examining which of these two procedures to use is that there are different ways to look for solutions that in turn may vary depending on the starting point values used. As will be discussed in Chapter 7, results showed that models based on an advanced basis performed as well or better than those based on a reinitialized basis.

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21 In GAMS, setting bratio=1 will cause all existing basis information to be discarded while setting bratio=0 forces GAMS to construct a basis using whatever information is available (Brooke *et al* 1998).

3.3.5 Changes to the Model

This section describes changes to the model that were made as the analysis progressed. Some constraints were modified and other new constraints were added. Because of the existence of thin markets for garden products, a sales constraint was added to both double sector and tri-sector models to restrict the quantity of possible garden sales. The garden sales constraint is discussed further in Section 4.5.10. The garden sales constraint was formulated as follows:

$$(3.7)\quad SELL_{jk} \leq SELLPCT_j * YLD_{jk} * PROD_j \ \forall j = 1$$
$$given\, that\, \text{sec}tor\ j = 1\ (gardens)$$

where parameter $SELLPCT_j$ is the ratio of the quantity of garden output sold to quantity of garden output produced and other variables are as defined in Sections 3.3.1.2 and 3.3.1.3. Equation 3.7 states that quantity of garden crops sold is less than or equal to observed sales by state.

As was the case for gardens, the existence of a thin market for woodlands production also resulted in the inclusion of a woodlands sales constraint in tri-sector models. The woodlands sales constraint was formulated as follows:

$$(3.8)\quad SELL_{jk} \leq WOODSOLD \qquad \forall j = 3$$
$$given\ that\ \text{sec}\,tor\ \ j = 3\ (woodlands\ )$$

where parameter WOODSOLD is the observed mean woodlands sales and $SELL_{jk}$ is as defined in Section 3.3.1.2. Equation 3.8 states that woodlands sales cannot exceed mean observed sales per wealth quartile. Whereas the gardens sales constraint was set as a proportion of yield, the woodlands sales constraint was set to be less than or equal to a fixed value equal to observed sales. The different constructs were used because garden production was restricted by the garden area constraint while there was no area constraint to limit woodlands production.

Preliminary analysis of tri-sector models necessitated a change in model structure to formulate different labour constraints for dryland agriculture, gardens, and woodlands. The labour constraint for the woodlands sector does not allow labour to be hired since labour is generally only observed to be hired for agricultural activities. The total labour constraint was formulated as follows:

(3.9) $FA + FW \leq FAW$

where FA and FW are activities representing hours of household labour allocated to agriculture and woodlands production, respectively, and parameter FAW is the hours of household labour available for use in agriculture and woodlands production. Equation 3.9 states that the sum of family labour hours allocated to dryland agriculture, gardens and woodland production is less than or equal to the stock of family labour hours available for use in these three sectors.

The constraint for labour use in the woodlands sector was formulated as follows:

(3.10) $\sum_j (l_j * PROD_j) \leq FW \quad \forall j = 3$

$given\,that\ \text{sector}\ j = 3\ (woodlands)$

where all variables are defined as previously. Equation 3.10 states that family labour use in woodlands production cannot exceed the number of family labour hours allocated to woodlands production.

The constraint for labour use in agricultural production was formulated as follows:

$$(3.11)\quad \sum_j (l_j * PROD_j) - HL \leq \ FA \quad \forall j = 1,2$$
$$\textit{given that } \text{sector } j = 1\ (gardens)\ , j = 2\ (dryland\ agriculture)$$

where all variables are defined as previously. Equation 3.11 states that labour use in agricultural production cannot exceed the sum of family and hired labour hours allocated to agricultural production[22].

The household cash income constraint (equation 3.3-6) was modified for the purpose of policy simulations based on the microcredit scheme to include the value of the credit as follows:

$$(3.12)\quad \sum_j (VC_j * PROD_j) + (w_H * HL) + (P_{DL} * DL) + \sum_j (P_{bjk} * BUY_{jk}) + DOMEXP_k \quad \leq$$
$$\sum_j (P_{sjk} * SELL_{jk}) + LOAN \quad \forall k$$

where LOAN is the value of cash received from the microcredit scheme and all other variables are defined as previously.

22 The allocation of labour between agriculture and woodlands is endogenous. It is possible to have zero hours allocated to woodlands; that is, labour can be allocated to agriculture and/or woodlands, or to none of them. The assumption built into this study was that hired labour was used for agriculture only and not in the woodlands sector.

CHAPTER 4

Study Sites, Data and Parameters

4.1 Introduction

This chapter presents a description of the study sites, data used in the study and the procedures used to derive parameters that were used in modelling. Characteristics of surveyed households are highlighted. A more detailed description of the primary data collected and data collection methods is contained in Campbell *et al* (2002).

4.2 Survey Data

This section describes the instruments and methods used to collect primary data.

4.2.1 The Study Sites

This study is based on household-farm level data collected for Zimbabwean smallholder agricultural producers. A household survey on livelihoods was conducted by the Institute of Environmental Studies (University of Zimbabwe) in collaboration with the Department of Research and Specialist Services (Zimbabwe), Centre for Ecology and Hydrology (UK) and the Centre for International Forestry Research (CIFOR). The survey was carried out in the Romwe and Mutangi areas of Chivi District, Masvingo Province.

These areas were located in natural regions[23] III and IV, respectively. Two sites (Romwe and Mutangi) were selected to try and ensure a degree of diversity in households. The author did not organize the survey and therefore used primary data supplied by other researchers. The author did visit and stay in the survey areas for one month (February-March 2001) in order to become familiarized with the area, data collection procedures used and issues arising from data collection, and to gain a better insight into the livelihoods of the households. The objectives of the field visit were to exchange notes with researchers involved in the survey, and to collect secondary data.

4.2.2 Field Survey and Nature of Data Collected

Data were collected using a household questionnaire. The survey was conducted as a quarterly household income and expenditure survey, over 15 months from late 1998 to early 2000. The focus of the survey was on tracking how households used their available resources in the pursuit of livelihoods, and the returns that they received from these activities. Because of the seasonal variability facing households in these villages, data were collected quarterly. Furthermore, several visits were made to each household within each quarter in order to gain sufficient observations regarding data that were only likely to be accurately recalled within short time spans. For the analysis, weekly data are considered to be more reliable than quarterly data because of the shorter recall period involved. The first visit (round) in each quarter was structured around major activities for which households could reasonably be expected to remember details over a three-

23 Zimbabwe is divided into five natural regions on the basis of annual rainfall, vegetation, edaphic factors and other agricultural related factors. Natural region I receives the highest rainfall while natural region V receives the lowest.

month period. The subsequent five visits (rounds 2-6) in each quarter were used to collect information from short-term recall questions. The data were thus highly disaggregated. The structure of the survey is indicated in Table 4.1.

4.2.3 The Sample

There were 417 households located in 10 villages in Romwe while Mutangi had 453 households in 18 villages. A stratified random sample was taken with households selected from each of the villages in proportion to the total number of households in each location. The objective was to select 125 households from each of the two research sites. There were no landless households in the survey areas. The survey was drawn from a complete list of village households. Some households were dropped from Mutangi due to enumerator problems. The analysis is based on a final sample of 199 households of which 124 were in Romwe and 75 were in Mutangi.

4.2.4 Enumerators and Supervisors

The surveys were conducted by 10 trained enumerators. Each enumerator was assigned approximately 25 households. Individual household interviews lasted less than an hour. Enumerators were supervised by research assistants based in the survey areas. Research supervisors based in Harare made occasional visits to check on the data collection process thereby ensuring high quality data returns. Data entry was done in Harare.

4.2.5 Measurement Units

Physical measures of production were collected as part of the survey. Measurement units commonly used by communal households are often not 'standard' units (e.g., contours for area, wheelbarrows and carts for amounts of manure). However, to ensure a common understanding the survey used these locally understood units, most of which were based on volume. In order to convert the resulting values to standard units, a separate survey was conducted in which local units were measured in standard units. The conversions used are documented in Tables 4.2a and 4.2b.

4.3 Representative Households

This section describes key characteristics of the representative households used in this study. These characteristics provide an indication of the variation in resource endowments at the household level.

4.3.1 Criteria for Defining Representative Households

Wealth forms the primary criterion for defining representative households used in this study. Wealth is an important tool for classifying agricultural households because it influences access to resources that are used by the household. Therefore, wealth influences much of what the household does and is capable of doing. Classifications based on wealth have policy implications since policy statements can be given for particular groups of households with similar asset bases. Another major reason for looking at wealth groups is that donors (e.g., non-governmental organisations and other development related agencies) are interested in how wealth is distributed and whether they are actually helping the poorest, and not just the households who are better off. A wealth index was developed to differentiate households by wealth status.

4.3.1.1 Preliminary Analysis of Household Perceptions of Wealth

Wealth ranking, a Participatory Rural Appraisal (PRA) technique, was undertaken for three villages centred on the Romwe physical catchment to explore local perceptions of household stratification[24]. The key informants regarded 'wealth' as the main differentiating factor for household stratification. In the wealth ranking, 10% of the households were classified as being better off, 19% as average, 36% as poor and 35% in the poorest category. Variables identified as important by the key informants in characterizing households in different wealth groups were: type of shelter; livestock numbers; ownership of farm implements; yields achieved by dryland production; amount of remittances received; degree of food security; ability to offer food to guests; nutritional status of the family; level of education of children and the kinds of schools attended by children. The wealth index that was developed used variables that were identified as important criteria in differentiating households in the PRA wealth ranking.

4.3.1.2 Creating the Wealth Index and Wealth Quartiles

This section provides a description of the procedures that were undertaken during the creation of the wealth index. As stated above, the author was not involved in the creation of the wealth index. The wealth index was created using Principal Components Analysis

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24 The participatory rural appraisal exercise was undertaken by Professor Bruce Campbell and other researchers. The author was not involved in the exercises.

(PCA). PCA is a multivariate statistical technique which is often used for data compression, for change detection and for long sequence time series evaluation (Eastman and Fulk 1993). The technique essentially consists of choosing uncorrelated linear combinations of the variables in such a way that each successively extracted linear combination, called a principal component, has a smaller variance. If the variables have significant linear inter-correlations, the first few components will account for a large part of the total variance[25].

The technique involved combining several original variables into a few derived variables. In this case, there was a single derived variable, which was interpreted as a wealth index. Original variables investigated included area of dryland fields, area of irrigated land, type of shelter, remittances in the period December 1998 to February 1999, numbers of cattle, numbers of goats, numbers of donkeys, numbers of various types of productive equipment (e.g., machete, wheelbarrow, plough) and numbers of various types of household equipment (e.g., mortar and pestle, sewing machine etc.). A number of analyses were conducted in creating the wealth index. In the initial analysis, the first principal component (the derived variable) accounted for 21% of the variation in the original variables and had high loadings for many of the variables[26]. In particular, numbers of beds, numbers of chairs and numbers of cattle had loadings greater than or equal to 0.70. It was reasoned that numbers of beds and chairs were probably more related to household size than wealth, so in the second analysis these kinds of variables

25 Source: http://www.geog.mcgill.ca/grad/landc/pca.html

26 A loading reflects the degree to which the original variable contributes to the derived variable.

(e.g., beds, cooking pots, chairs, tables) were removed. In this second analysis variables with loadings of greater than or equal to 0.45 were identified, and these variables were used in the third analysis[27].

In the third analysis, the four variables with the highest loadings were number of cattle (0.19 being the coefficient for this variable in the principal component), ownership of scotchcarts (0.19), ownership of wheelbarrows (0.17) and type of shelter (0.16). Scoones (1995) also identified these variables as being related to wealth. Other variables included in the analysis but with lesser loadings were ownership of televisions (0.15), ownership of sewing machines (0.14), numbers of goats (0.12), ownership of solar panels (0.12), numbers of donkeys (0.11), ownership of radios (0.11), ownership of drums (0.11), ownership of ploughs (0.11) and ownership of spades (0.07). When calculating the wealth index, these coefficients were multiplied by the standardised values of the respective variables. The wealth index accounted for 31% of the variation in the original variables used in the analysis.

The resulting index was used to divide the sample of 199 cases into wealth quartiles with 49-50 households in each group. The four wealth groups (25%, 25-50%, 50-75% and the top 25%) are used in this study as the primary criterion for defining characteristics of the representative households. Wealth groups are also referred in the discussion that follows as wealth quartiles 1, 2, 3 and 4, respectively, where "higher" numbered quartiles refer to

27 By using fewer variables, fewer cases are removed due to listwise deletion that occurs in PCA when any one particular variable has a missing value.

wealthier households.

4.3.2 Characteristics of Representative Households by Wealth Quartile

The data for the representative households were derived as the mean values of the data for individual households in the respective wealth quartiles. The distribution of households among wealth quartiles was almost identical in Romwe and Mutangi (Table 4.3). However, this finding should not be interpreted to imply that the composition of wealth is the same in both sites. For example, Table 4.4 shows that there were more cattle, and larger areas of dryland fields and gardens in Mutangi than in Romwe. However, field sizes were not necessarily wealth related; they were probably larger in Mutangi because of the widespread nutrient-poor soils, resulting in more extensive production systems, with a higher portion of fallow land. In addition, Mutangi had less hilly terrain than Romwe, and more cultivatable area.

4.3.2.1 Household Size, Composition and Education Levels

There was an average of 6.51 members per household. Wealthier households tended to have more adult males and females, while there were no differences among wealth quartiles for children and minors. In all wealth quartiles, there were more resident females than males, indicating that males were more likely to seek off-farm work (Table 4.5).

Data on household size and composition provide an indication of the household's labour resource that can be allocated to dryland agriculture, gardens and woodlands sectors. The household's labour resource base is a key determinant of the amount of family labour hours that can be allocated to production activities, as represented in equation 3.3-3. With respect to education level, there was no difference among wealth quartiles for primary education. However, evidence of secondary education was associated with higher wealth households. There also tended to be a correlation between "no education" and the lower wealth quartiles. Overall, there were few people with post-secondary school education (Table 4.6). The information on academic levels of the household provides an indication of the household's off-farm income earning potential. In general, household members with higher levels of education seek off-farm employment and remit some of their income back to the household.

4.3.2.2 Land for Crop Production

Land is an important resource for smallholder agricultural producers. As expected, the wealthiest group owned more dryland acres, compared to the poorest (Table 4.7). There were no statistically significant differences in the size of garden acres owned among paired wealth quartiles. The results of land ownership were used to establish endowments for the models constructed in this study. The household's land endowment forms the right hand side variable for the land constraint; that is, equation 3.3-1.

4.3.2.3 Livestock Ownership Patterns

Results suggest that there were differences amongst wealth quartiles for numbers of cattle, goats and donkeys (Table 4.8). Wealthier households had higher mean livestock numbers. Thirty four percent of the households did not own draught animals (cattle and/or donkeys). These households were likely to experience draught power problems and reduced yield due to late planting. Livestock ownership patterns determine the household's draught animal endowments in terms of the amount of hours of draught power that the household have available from their own herd in equation 3.3-4. Livestock ownership is a key determinant of wealth status among smallholder farmers.

4.3.2.4 Household Use of Time

Household labour resources were used in numerous activities to contribute to household livelihoods. As these activities were known to vary seasonally and by age and gender, data on time spent in various activities were collected to analyse potential differences. Productivity was assessed in terms of two age groups, adults versus children.

Table 4.9 presents the mean hours spent by adult females, adult males, and children, on various activities. After sleep and domestic activities, dryland crop fields received the most attention in terms of time. Adult males contributed 18% less time to agricultural and domestic activities than did females, spending more time on leisure and academic pursuits. Adult females contributed much more to dryland agriculture and gardens production than did adult males who in turn spent more time on livestock production. Leisure averaged out to 6.86 hours/day, with adult males having more hours compared to adult females. Children spent more time in academic activities compared to adult males and females. Adult females contributed about 50% of a 24-hour day to agricultural and domestic work compared to a contribution of about 30% for children.

The absolute amount of time given to gardens production was not very high but when the time input to dryland agriculture and gardens was calculated on a per unit of area basis, gardens production was much more labour intensive (i.e., two times more than dryland agriculture for wealth quartiles 2-4), with most of this labour being contributed by female members (Table 4.9). Households in the top wealth quartile appeared to apply much more labour to gardens than households in lower quartiles, but there was much variability and the differences were not statistically significant. The pattern of labour by wealth class for dryland agriculture was not clear, as wealthier households had more labour-saving devices and they hired more labour. Results on household time use are used to determine the right hand side variable (i.e., labour endowment) of the time constraint; that is, equation 3.3-3.

4.3.2.5 Cash Expenditures

Domestic expenditures accounted for 80% of total household expenditures (highest) while woodlands accounted for one percent (lowest). Table 4.10 shows that expenditures differed between wealth quartiles. Based on weekly recall data for all expenditures, there were greater amounts expended among wealthier families for all sectors except gardening and woodland use (i.e., the two lowest expenditure sectors). Results were similar for quarterly recall data for major expenditures, except that there was significantly more spent by households in the top wealth quartile on gardens as well. Large domestic expenditures (e.g., school fees) were approximately five times greater for wealthy than for poor households. The results on cash expenditures are used to determine the value of variable costs per unit (see section 4.5.9.1) and the value of cross-subsidies between sectors (see section 4.5.9.2).

4.4 Household Sectors Modelled

Table 4.11 contains a listing of household sectors as defined by the researchers who were involved in designing the household livelihoods survey. These sectors define the productive activities that households undertake given the assets they have at their disposal.

Dryland agriculture, gardens and woodlands are the three sectors explicitly modelled in this study. These three sectors are not exogenous to the household and account for 32.2% of total household cash income (Table 4.12). The wage labour (apart from hiring labour) and remittance sectors, while playing an important role in contributing to household income, are considered to be exogenous in this study and are therefore not modelled explicitly[28]. Behaviour in the domestic sector is not modelled explicitly because it is difficult to value the services rendered to the household. The domestic sector supports all sectors and receives returns from all other sectors.

A preliminary analysis of descriptive statistics on values of livestock sales and purchases plus their contribution to household income suggested that livestock selling and purchasing decisions were relatively fixed in the short run, when considered on an annual

28 The household is assumed to be a price taker in the wage labour market.

basis. Activities pertaining to labour decisions on livestock plus changes in the herd due to birth were therefore considered fixed within the time frame of the models solved in this study.

Hedden-Dunkhorst (1993) excludes livestock activities and contends that it is acceptable to handle livestock production as constants because crop and livestock production activities can be regarded as being relatively independent from each other. Previous studies have also concluded that livestock sales, especially for cattle, are not a significant activity in the communal areas (Kundhlande 2000). The one aspect of the livestock sector included in the models is draught use and draught hire. The value of draught hire enters into the income equation, that is, equation 3.3-6. Previous studies in Zimbabwe have emphasized the constraints of insufficient draught (e.g. Gesellschaft für Agrarprojekte 1987). The analysis in this study is based on three explicit sectors: dryland agriculture, gardens and woodlands.

4.5 Derivation of Model Parameters

This section presents a discussion of the data and methods used to derive parameters for the empirical models. Parameters were derived using primary and secondary data sources. Most parameters were derived as mean values for each wealth quartile since the study focused on analysing the microeconomic behaviour of representative households.

4.5.1 States of Nature and Associated Probabilities

Ten states of nature (k) are modelled in this study. The intent was to create states of nature describing potential situations that may influence household choices. The states of nature are based on historical data for a representative ten-year time frame (1987-1996). Ideally, data for the past 10 years preceding the survey should be used. However there were problems with secondary data for national crop prices in 1997. There appeared to be errors in the national crop price data that could not be explained[29]. The year 1996 was chosen as the base year (index = 1); that is, state of nature 10 for historical price and yield data because it was closest (in time) to the survey year. The ten states of nature were assumed to be indicative of possible events. Each state of nature was assumed to have an equal probability of occurrence (p_k) of 0.1.

4.5.2 Bounds of the Coefficient of Absolute Risk Aversion

Household risk preferences are incorporated in the objective function via the risk aversion parameter, (λ), as shown in equation 3.3. The procedures for estimating the risk parameter are documented in Chapter 2. The process of searching for risk aversion levels involves varying λ. In order to do so, values of the upper and lower bounds of the coefficient of absolute risk aversion (r_a), parameters *a* and *b* in equation 3.3 are required. As indicated in Chapter 2, other studies have estimated widely variable empirical estimates of r_a that are not easily compared. Values of the coefficient of relative risk

29 The time series of national prices presented sudden unexplained changes in prices for 1997. For example, the real price of cotton for 1997 was given as zero while there was a considerable jump in the producer price compared to that for 1996. It is not clear whether there were any changes in policy accounting for this price increase. Given this scenario, the approach adopted was to base the states of nature on the ten years preceding 1997; that is, 1987 to 1996. It is possible that for some years in the time series a drought was experienced and this may explain some of the price disparities.

aversion (r_r) were used to calculate the bounds for r_a. The process of determining values of r_a was designed to include a broad wealth base thereby ensuring that a large range of values of r_a would be searched to find an optimal solution. The following steps were taken in calculating upper and lower bounds of r_a.

First, three values of income were calculated for each wealth quartile as follows. The mean income for each wealth quartile was calculated as an average of summed incomes derived from all sectors. For each wealth quartile, an upper bound on income was calculated as 150% of mean income while a lower bound was calculated as 50% of the mean income. The upper and lower bounds on income values were calculated to define a reasonable range of income values over which values of r_a could be calculated, based on the relationship between r_a and r_r.

Second, income was capitalized into wealth using the formula: $W = I/i$ where W is wealth, I is income and *i* is a discounting rate. Three discount rates of 10, 30 and 50% were used to discount each of the three income levels for each wealth quartile[30]. Kundhlande (2000) calculated mean rates of time preference for a sample of Zimbabwean smallholder farmers that were centred around 30%. Discount rates of 10% and 50% were used to increase the range over which values of r_a could be calculated. A total of nine wealth values were computed for each wealth quartile; that is, three different income values were each discounted using three different discount rates. Third, each wealth

30 Campbell *et al* (2000) used a base year discount rate of 17% as well as lower and upper rates of 8% and 25% respectively in their studies of Magwende and Chivi communal areas of Zimbabwe.

value (W) was applied to the formula $r_a = r_r/W$ where r_a is the coefficient of absolute risk aversion and r_r is the coefficient of relative risk aversion. Values of 0.5 and 4.0 were used for r_r in order to search over a broad range of values[31]. A total of 18 values of r_a were calculated per wealth quartile. The highest and lowest values of the 18 values for each quartile was used as the upper and lower bounds of r_a in the simulation analysis. The values are presented in Table 4.13.

The resulting estimates for the upper and lower bounds of the coefficient of absolute risk aversion were used in the analysis to limit the range of risk aversion under consideration. Each household model was resolved, varying the level of risk aversion in small steps. The size of the steps was computed with the intent to ensure that the values of the coefficient of absolute risk aversion spanned the range between the upper and lower bounds, over 1000 runs[32]. The process of investigating the size of the steps was done by tracking marginal changes in the coefficient of absolute risk aversion as the risk parameter (λ) changed and then checking to see how large a value of the risk parameter was needed to get close to the upper bound of the coefficient of absolute risk aversion. A compromise on the size of the steps for each wealth quartile was arrived at to ensure that there were a reasonable number of iterations and that no large gaps were left towards the upper and lower bounds of the coefficients of absolute risk aversion. The value of the coefficient of absolute risk aversion at each change in step was calculated using equation 2.26. The process of recovering the risk attitudes of the household involved assessing

31 Little and Mirrlees (1974) suggest that r_r will be close to 2 while Hardaker *et al* (1997) suggested a range of 0.5-4.0. A broad range of values was used in this study.
32 The runs were restricted to 1000 because of a computer-programming limit for the GAMS program.

predicted behaviour versus observed behaviour. The value of the risk parameter that minimized the squared deviation between predicted and observed behaviour was taken to be the "best" measure of the household's risk attitudes.

4.5.3 Calculating Parameters Used in Household Models For the Base Year

Data obtained from the survey were very disaggregated. These data were aggregated by sector to conform to the structure of model used in this study. Problems were encountered in aggregating data given that sectors such as woodlands were made up of a large and complex basket of diverse activities.

Aggregate prices for each sector were obtained by dividing the total value of production (in Z$), summed over all households in a wealth quartile, by the total weight of production (in kilograms) for those households. A similar method was used for calculating costs and yield for each wealth quartile. This procedure implicitly gave greater weighting to households with greater production. For example, a household using one acre for dryland agriculture production would be given a higher weighting, in terms of contributing to average yield, compared to a household using 0.6 acres for dryland agriculture production.

Appendix B provides the specific procedures that were used to derive aggregate prices, costs and yields. Aggregate yields and aggregate prices were used to derive yield and price series as explained in the following sections. Aggregate cost figures were used in calculating net returns to labour (Appendix B). Table 4.14 presents base year values of yields, variable costs and prices that were used in the analysis. Prices calculated were the same for all wealth quartiles. Yield and cost figures for dryland agriculture and gardens varied by wealth. Data suggested higher wealth levels generally resulted in higher yields. However, there was no variation in woodlands yields and costs by wealth quartile. Woodlands variable costs were set to zero since 75% of the observations had variable costs of zero and remaining values were small.

4.5.4 Value of Production Over Time

The value of production was computed as the product of price and yield. Because time series data were lacking, a short questionnaire was designed and posted to experts in Zimbabwe to seek their opinion on the variability of values of output of different sectors relative to that for dryland agriculture[33]. Table 4.15 contains the average values of the variability of values of output index for different sectors relative to that for dryland agriculture based on responses by experts. Results suggested that all sectors were much less variable than dryland agriculture. Woodlands values of output were the least variable while livestock values of output had the highest variability relative to that for dryland agriculture (Table 4.15). These expert opinion values were used to adjust variability of yield and price series for each sector. The following sections present information on yield and price series that were derived and used to compute values of production for the 10 states of nature.

33 Expert opinion was sought from Professor Bruce Campbell (then Director of the University of Zimbabwe's Institute of Environmental Studies) and Manyewu Mutamba, a Research Assistant in the same unit. Campbell and Mutamba were core researchers in the interdisplinary research project on household livelihoods and were therefore considered experts based on their knowledge of the socio-economic activities of the households. They had spent three full years working and sometimes living in the area and were very knowledgeable about the activities undertaken by the agricultural producers. Questionnaire returns were obtained from these two experts only.

4.5.4.1 Yield Series

Yield series by sector in each state of nature were necessary for parameter YLD_{jk} in equation 3.3-2. However, there were no historical household level yield series available for dryland agriculture, gardens and woodlands sectors. Therefore, it was necessary to create a time series of yields for the 10 states of nature. Observed yields (kg/acre for crops and kg/hour for woodlands) derived from Table 4.14 were used to derive household yield series. Yields were calculated for each wealth quartile in order to capture differences in production technology or management practice that could be attributable to wealth. Observed yields were used for state of nature 10 and values for the other nine states of nature were derived from this base value. The following sections describe how base values of yields were extrapolated to form yield series.

4.5.4.1.1 Dryland Agriculture Yield Series

Ideally, a time series of dryland agriculture yield data would have been used for the other nine states of nature, but the necessary household data were not available. The household dryland agriculture yield series was created using relative variation in a time series of aggregate yields at a district level for four local grains (maize, sorghum, rapoko and mhunga) to extend the observed household aggregate yield (of the full set of locally grown dryland crops) into a time series[34]. Implicit in these calculations is the assumption

34 The data was obtained from Dr. Peter Frost, a Research Associate at the Institute of Environmental Studies (University of Zimbabwe). The data were originally from the Department of Agricultural, Technical and Extension Services (AGRITEX) Crop Production Estimates and were subsequently obtained from Famine Early Warning System (FEWS), Harare.

that variability at the district level is equivalent to variability at the household level, for dryland yields. Table 4.16 provides the household yield series for dryland agriculture by wealth quartile and state of nature. Appendix C, Section C1.1 provides the specific procedures that were used to derive the household dryland agriculture yield series.

4.5.4.1.2 Gardens Yield Series

Ideally, household level garden yield data would have been used to calculate yields for the other nine states of nature, but the household data were not available. A household garden yield series was created through the use of two key assumptions. First, it was assumed that the general pattern of garden yields at the household level would *mimic* the historical pattern of national yields for an equivalent set of crops. In this case, the data used were national time series yields for melons and vegetables. However, it was recognized that the degree of year to year variability of yields at the national level probably underestimates the yield variability at the household level. Thus, the second key assumption is that the relationship between national and household garden yield variability (i.e., relative variability) is similar to that for a crop for which national and household yields were available; specifically dryland agriculture yields (proxied by maize at the national level).

Household dryland yield series derived in Section 4.5.4.1.1 were available by wealth quartile. The following procedures were undertaken in deriving household garden yield series by wealth quartile. First, the relationship between variability in national maize and household dryland agriculture yield series was derived. The coefficient of variation for maize at national level was 0.42 while that for dryland agriculture at household level was 0.66. Thus household yields for dryland agriculture were 1.6 times more variable than national yields. It was assumed that a similar relative relationship between national and household yields held for vegetables and melons since both dryland agriculture and garden crops were affected by the same environmental conditions. Therefore, the degree of variability in national "garden" yields was increased by a factor consistent with the relative variability in maize/dryland agriculture yields. Yield variability indices for vegetables and melons were derived. These indices were then applied to state of nature 10 yields for gardens to derive household garden yield series by wealth quartile. Table 4.17 provides the household garden yield series by wealth quartile for each state of nature. Appendix C, Section C1.2 provides the procedures that were used to derive the household garden yield series.

4.5.4.1.3 Woodlands Yield Series

Ideally, household time series of woodlands yield data would have been used for the other nine states of nature, but the household data were not available. The household woodlands yield series was created by imposing the same degree of relative variability in the household yields for dryland agriculture on the household woodlands yields, using the observed yield for state of nature 10 as the base. Expert opinion was used to adjust variability in woodland yields relative to that for dryland agriculture. The woodlands yield series were subsequently derived by multiplying the observed yield of 8.5kg/hour derived from Table 4.14 by the index of household dryland agriculture yields adjusted to levels appropriate for woodlands variability. The woodlands yield series are presented in

Table 4.18. Appendix C, Section C1.3 details the procedures that were used to derive the household woodlands yield series.

4.5.4.2 Price Series

Price data were collected in the household survey for cases where goods and services were sold by the sample households. Base year prices for dryland agriculture, gardens and woodlands were needed for each of the ten states of nature in this study for the purpose of valuing household production, consumption, sales and buying activities. However, only a single year's observation of prices collected during the survey was available for use in this study.

The approach adopted to overcome the lack of household historical price data was to create price series using the observed single year prices, time series national historical price data for some dryland crops and a variability rating for output values based on expert opinion[35] (Table 4.15). Price series for each sector in each state of nature for consumption, sales and buying activities are represented by parameters P_{cjk}, P_{sjk} and P_{bjk} in equation 3.3. Subsections that follow present information pertaining to the derivation of price series for dryland agriculture, gardens and woodlands.

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35 The basket of dryland crops for which national prices were available was a subset of the dryland crops grown locally.

4.5.4.2.1 Dryland Agriculture Price Series

The single year's aggregate price of Z$5.5/kg derived from Table 4.14 was used to develop a household price series for dryland agriculture based on the national price series for dryland crops. In essence, variability around the base year observation in the national price series was used, in proportion to the household prices, to create a time series of ten household values for prices. Table 4.19 provides the household dryland agriculture price series. Appendix C, Section C2.1 provides the specific procedures that were used to derive the household dryland agriculture price series.

4.5.4.2.2 Gardens Price Series

Unlike dryland agriculture prices, there were no national price series available for garden commodities. Therefore the household garden price series was created by using the variation in the household price series calculated for dryland agriculture, adjusted for expert opinion (Table 4.15), in terms of the coefficient of variation of values of output for gardens relative to that for dryland agriculture.

The garden price series that was originally derived using this method resulted in problems with respect to the degree of variability in value of production[36]. Specifically, the value of garden output (price multiplied by quantity) for the ten states of nature was only 5% as variable as the value of dryland agriculture output (Appendix C, Section

36 Dryland agriculture and woodlands sectors did not suffer from this problem.

C2.2). Expert opinion suggested that the value of garden output was 25% as variable as that for dryland agriculture (Table 4.15). This result suggested that a greater degree of variability in garden prices was required in order to attain a level of variability in garden values of output consistent with expert opinion. It was determined that garden prices needed to be 2.7 times as variable as dryland agriculture prices (Table 4.19) to accomplish this result. This relative variability made sense given the lack of ability to store garden produce. This probably contributes to higher garden price variability. Moreover, basing garden prices on dryland prices might also not be entirely appropriate since dryland agriculture prices were more stable because of government controls. The resulting household garden price series was applied to all wealth groups. Table 4.19 provides the household garden price series. Appendix C, Section C2.2 provides the specific procedures that were used to derive the household garden price series.

4.5.4.2.3 Woodlands Price Series

As with garden prices, there were also no national price series available for woodlands. Therefore the household woodlands price series was created by using the variation in the household dryland agriculture price series, adjusted for expert opinion (Table 4.15). As explained in Appendix B, Section B1.2, an aggregate woodlands price of Z$0.25/kg was selected and applied to all wealth groups. The same process used to generate garden price series was applied and used to generate a household woodlands price series. However, there was no need to further adjust the variability of woodlands prices (as was required for garden prices) since the variability of values of output for woodlands relative to dryland agriculture reflected the relative variability obtained from expert opinion

(Table 4.15). Table 4.19 provides the household woodlands price series. Appendix C, Section C2.3 provides the specific procedures that were used to derive the household woodlands price series.

4.5.5 Time Use Parameters

Household time use is expressed in adult-equivalent hours with males and females being weighted equally. In this study, an hour of child labour is assumed to be equivalent to half an hour of adult labour in terms of productivity[37]. Parameter F in equation 3.3-3 represents family labour time available for use in dryland agriculture and gardens in the double sector household models. Parameter FAW in equation 3.9 represents family labour time available for use in dryland agriculture, gardens and woodlands production in the tri-sector household models. Parameters F and FAW are calculated as the sum of the amount of family labour time spent by males, females and children, in adult equivalent units.

Labour requirements for each sector (l_j), in hours per acre per household used in equation 3.3-3, were derived by dividing total annual household time devoted to each sector by the acreage planted in the case of dryland agriculture and gardens. The woodlands sector was communally owned. As noted earlier, the woodlands activity was measured in terms of time spent harvesting or collecting. Thus an implicit labour requirement coefficient of one is specified for the woodlands activity. Labour requirements per unit by sector for dryland agriculture, gardens and woodlands are presented in Table B.2 in Appendix B.

37 Johnson (1990) used adult equivalent units of 1.0 for adult males, 0.8 for adult females and 0.4 for children aged 7-14.

4.5.6 Draught Power Related Parameters

Information derived from the survey on household livestock inventory was used to compute the household's draught supply endowment in hours (D); that is, the right hand side parameter value for equation 3.3-4. The potential draught supply per household was obtained by summing potential hours of work that could be obtained from each draught animal (cattle and donkeys)[38]. Household draught animal supply was quantified in draught cattle equivalent hours. Results of the survey suggested that an acre of dryland agricultural production required three hours of draught power. Thus the draught power requirement (d_j) in equation 3.3-4 for dryland agriculture was three hours per acre. Draught power requirements for gardens and woodlands were set at zero as draught was not used in these sectors.

Parameter P_{DL} in equation 3.3-6 represents the cost of hiring draught animals in Z$/hour. Survey results indicated that the cost of hiring draught power was Z$200/hour. Given the poor economic conditions prevailing in Zimbabwe, not many people could afford to hire draught animals at that cost. In the model simulations undertaken, draught power hire rates of Z$200, Z$100 and Z$50/hour were explored for sensitivity analysis. Few surveyed households reported hiring draught animals despite the fact that 34% of the households did not own draught animals (cattle and/or donkeys). This anomaly may be attributable to the fact that households could get access to draught power through arrangements that do not involve cash transactions (e.g., in-kind payments in the form of

38 Manyewu Mutamba, one of the local experts (see footnote 33), suggested that one hour of work by a span of two draught cattle was equivalent to three hours of work by a span of four draught donkeys.

labour or grain).

4.5.7 Natural Resource Base Parameters

The household land base in acres (END_j) in equation 3.3-1 represents the household's land endowment. Data on land area planted were collected on a quarterly basis. Households were asked to state the amount of dryland agriculture and gardens area planted in each quarter. Problems arose in validating some of the planted area data. One problem was that in some cases, the total area planted over the four quarters exceeded the household's land endowment. This can be attributed to households reporting cumulative rather than marginal amounts planted. Therefore, the maximum area planted over four quarters was considered to be the measure of the area planted in a year for both dryland agriculture and gardens. For a few observations, the maximum area planted per quarter per household exceeded the reported land endowment. In such cases, the maximum area planted over the four quarters was considered to be the land endowment. The area planted was then computed as a simple average over all households in each wealth quartile.

4.5.8 Labour Wage Rates

Two sets of wage data were collected. One data set was collected on a quarterly basis while the other was collected using a weekly recall time frame over six rounds of data collection (Table 4.1). The quarterly data set referred specifically to wage income received by each resident household member and the months and/or days worked during the last three months. The weekly recall data set captured cash income received from different income sources/activities by one member of each of the adult male, adult female and child categories over the past week. The weekly data captured wage income, income from trading, and self-employment income. Quarterly data were used in the computation of wage rates given that those data specifically related to wage income. The quarterly data were therefore seen to be more accurate in terms of capturing earned income as well as the number of days worked.

The wage data included income received from jobs done outside the survey areas. It is possible that wages received from 'outside' jobs may have been higher than income received from the survey areas, thus biasing the daily wage rate upwards. A labour wage rate (w_H) of Z$9/hour was calculated based on an average daily wage rate of Z$72 for the two study sites. The calculations for the daily wage rate were based on an eight-hour working day. Adult male and female wage rates were considered to be the same. Given that the level of unemployment is high in Zimbabwe as a result of the prevailing poor economic conditions, the supply of labour would be very high at a labour wage rate of Z$9/hour. Employers might not be willing to pay a wage rate of Z$9/hour given that the supply of labour is high and workers would be willing to settle for a lower wage rate. Therefore, in the model simulations undertaken, labour wage rates of Z$9, Z$5 and Z$2/hour were explored for sensitivity analysis.

4.5.9 Expenditure Related Parameters

Procedures used to calculate variable costs per unit and expenditures channelled to other sectors by the sectors modelled in the double sector and tri-sector household models are discussed below.

4.5.9.1 Cash Variable Costs

Quarterly rather than weekly data from the survey were used for calculating variable costs because quarterly data were more specific to agricultural input expenditures than were weekly data (i.e., weekly data included various expenditures such as capital inputs and consumption). Relevant variable costs collected on a quarterly basis included expenditures on fertilizer, seed for planting and pesticides; that is, mainly large item purchases. As indicated in Section 4.5.3, aggregate variable costs for each sector were obtained by dividing the total variable costs of production (in Z$), summed over all households in a wealth quartile, by the total acres (or hours of woodlands) for those households. Table 4.14 presents values of variable costs (VC_j) per acre (per hour for woodlands) by sector and wealth quartile that are used in equation 3.3-6. Hired labour and draught power costs were excluded from variable costs since these input hiring activities were modelled explicitly.

4.5.9.2 Inter-Sector Expenditures

In this study, some sectors are assumed to be endogenous whilst others are exogenous. In reality, household sectors are interdependent. Each sector has income and expenditures and there may be cross-subsidization; that is, income from one sector may be used to offset a deficit in another. This implies that some of the costs in equation 3.3-6 represent income transferred to other sectors to "cover" deficits. It is in this light that an analysis of surpluses/deficits was performed by sector and by wealth quartile to estimate the level of expenditures in the double sector and tri-sector models that were used in other sectors. The following sectors were used in the analysis of inter-sector transfers: gardens, dryland agriculture, livestock, woodlands, domestic and remittances.

Inter-sector expenditures were derived by analysing surplus/deficit figures for each sector and wealth group using income and expenditure data. The detailed procedures that were followed in deriving inter-sector expenditures by state of nature are discussed in Appendix D. Results suggested that only the domestic sector was "subsidized" by the other sectors in terms of having a net deficit. Table 4.20 and Table 4.21 provide values of domestic expenditures for the double sector and tri-sector household models in each state of nature by wealth quartile. Domestic expenditures constitute a tax[39] on the endogenous sectors for the models solved in this study.

4.5.10 Sales Ratios

Preliminary model results showed evidence of cases where predicted sales volumes for some household production sectors were far greater than observed sales volumes. Such cases occurred primarily for gardens and woodlands sectors. This may be attributed to the characteristics of markets for the sectors analysed in the study. Markets for gardens and woodlands were local in nature. Thus households could sell limited quantities of surplus from gardens and woodlands. This justified the setting of upper limits on

39 Tax here refers to the fact that domestic expenditures were funded by transfers from other sectors since the domestic sector had a deficit.

quantities of gardens and woodlands products that could be sold. On the other hand, the market for dryland agriculture was national and surplus products could be sold. Thus there was no need of setting upper limits on quantities sold for dryland agriculture. Observed sales ratios, defined as the ratio of sales to total production (in physical terms) for dryland agriculture, gardens and woodlands are presented in Table 4.22.

The observed sales ratio for gardens for each wealth quartile was used to determine the parameter $SELLPCT_j$ in the sales constraint (equation 3.7). The parameter was required to limit the amount of garden production that representative households could sell in each state of nature, relative to the level of production in the model solutions. Thus, garden sales were not constrained by a fixed value, but instead the limit on sales was defined as a percentage of the level of production in the model. Unlike the case for garden production, there was no area limit on woodlands production. The upper limit on the selling constraint for woodlands was therefore set equal to the observed quantity sold. Parameter WOODSOLD in the woodlands sales constraint (equation 3.8) represents mean observed woodlands sales per wealth quartile.

Table 4.1 Household Survey Structure

Survey Segments	Date Conducted	Dates Covered	Type of Data Collected
Quarter 1			
Round 1	March 1999	Starting conditions; monthly activities from Dec. 98 to Feb. 99; weekly activities for a week in March 99	• Background information on the household (shelter, land size, demography); • Three month recall on large items, including remittances, salaries, wages, dryland crop production, major input costs, livestock dynamics, wood use patterns. • Weekly recall on other items (smaller items that are not easily remembered over a month period), including gardens production, livestock production (milk, draught etc.). • Water use (not quarter specific)
Rounds 2-6	March to April 99	March to April 99	• Weekly recall questions covering woodland harvesting, purchases of inputs, income sources for a male, female and child in the household • Daily recall for labour (i.e. what was done the previous day), for a male, female and child in the household
Quarter 2			
Round 1	June 1999	Monthly activities from March to May 99; weekly activities for a week in June 99	• Same items as for Quarter 1, Round 1, but excluded the background information that was relatively constant • Quarterly water use patterns
Rounds 2-6	June to July 99	June to July 99	• Same items as for Quarter 1, Rounds 2-6
Quarter 3			
Round 1	Sept. 99	Monthly activities from June to Aug. 99; weekly activities for a week in Sept. 99	• Same items as for Quarter 2, Round 1
Rounds 2-6	Sept. to Oct. 99	Sept. to Oct. 99	• Same items as for Quarter 1, Rounds 2-6
Quarter 4			
Round 1	Dec. 99	Monthly activities from Sept. to Nov. 99; weekly activities for a week in Dec.	• Same items as for Quarter 2, Round 1
Rounds 2-6	Dec. 99 to Feb. 2000	Dec. 99 to Feb. 2000	• Same items as for Quarter 1, Rounds 2-6
Quarter 5			
Round 1	April – May 2000 for Mutangi, and April to July 2000 for Romwe	Monthly activities from Dec 99 to Feb 2000; weekly recall for the time when the survey was done.	• Covered the same items as for Quarter 2, Round 1. • Additional background information for households (e.g. village name, organisations involved in, access to collective gardens)

Source: Campbell *et al*, 2002.

Table 4.2a Unit Conversions

Category	Informal Units	Standard Units
Area	Contour	1.5 acres
Crops	Scotchcart of maize	5 bags (250 kg)
	Bucket of maize	15 kg
	4 unshelled buckets g/nuts (1 shelled bucket)	15 kg shelled g/nuts
	3 unshelled buckets roundnuts (1 shelled bucket)	15 kg shelled roundnuts
	1 tea cup beans	500 g
	1 bucket beans	30 kg
	1 bale cotton	250 kg
	1 bundle vegetables	500 g
	1 cob maize	100 g
	Bucket of tomatoes	10 kg
	1 onion	500 g
	Bucket of sweet potato	10kg
Fuelwood	Scotch cart	250 kg
	Wheelbarrow	45 kg
	Headload/bundle	25 kg
	Individual log	4 kg
Poles/fibre	Scotchcart	250 kg
	Individual pole	4 kg
	Bundle/headload	25 kg
Wood for utensils	Average item	15 kg
Litter	Bucket	5 kg
	Scotchcart	250 kg
	Wheelbarrow	30 kg
Wild fruits/ animals	Bucket	5 kg
	1 kg sugar packet	0.25 kg
	Bundle	1 kg
	Individual	0.2 kg
	Cupful	0.2 kg
Thatch	Bundle	5 kg

Source: Campbell *et al*, 2002.

Table 4.2b Unit Conversions

Category	Informal Units	Standard Units
Time	1 acre	3 hours of draught power or 4.5 hours per contour
	1 cartload worth of transport	1.5 hours (calculated on the basis of the questionnaire survey – households reporting cartloads and hours were assumed to have on average the same amount of time devoted to transport – the average time used by households reporting hours was 1.5 hrs)
Meat	1 cow, oxen	100 kg of meats when slaughtered
	1 goat	15 kg of meats when slaughtered
	1 hen	1.5 kg of meat
Manure	Cartload	340 kg
	Wheelbarrow, bag	68 kg
Hides	1 cow, oxen	20 kg
	1 goat	2 kg
	Unspecified	10 kg

Source: Campbell *et al*, 2002.

Table 4.3 Number of Households in Each Wealth Quartile by Site

Areas	Wealth Quartile				Sample Size
	Lowest 25%	25-50%	50-75%	Top 25%	
Romwe	31	29	32	32	124
Mutangi	18	21	18	18	75
Overall	49	50	50	50	199

Source: Campbell et al, 2002.

Table 4.4 Differences in Wealth Indicators Between Romwe and Mutangi

Variables		Romwe	Mutangi
Dryland field areas (acres)		5.1	7.0
Gardens areas (acres) (% ownership of gardens in brackets)		0.37 (77%)	0.52 (85%)
Cattle numbers (% owning in brackets)		2.8 (52%)	3.9 (65%)
Ownership (% of households in the study area owning)	Scotchcarts	42	31
	Wheelbarrows	75	88
	TVs	10	6
Shelter type (% with metal or asbestos roofing)		38	33

Source: Campbell *et al*, 2002.

Table 4.5 Household Composition by Wealth Quartile

Variable	Wealth Quartile				One-way ANOVA, F test
	Lowest 25%	25-50%	50-75%	Top 25%	
Number of adult males[1]	1.2[a]	1.5[ab]	1.3[ab]	1.7[b]	*
Number of adult females[1]	1.5[a]	1.8[a]	1.8[ab]	2.4[b]	***
Number of children[2]	1.7	1.9	1.9	1.8	NS
Number of minors[3]	1.5	1.3	1.5	1.2	NS
Total number of household members	5.9	6.5	6.6	7.1	NS
Sample size	49	50	50	50	

Notes: Dunnett C test: means followed by a common superscripted letter imply the mean difference is not significant at a 5% level; NS = level of significance is > 5%; * = level of significance is 5%; *** = level of significance is 0.1%. The Dunnett C test is a multiple comparison test that does not assume equal variances of means. The One-Way ANOVA (Analysis of Variance) procedure produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable (SPSS Online Manual). Analysis of variance is used to test the hypothesis that several means are equal.

[1] Males or females greater than 16 years of age; [2] Children who are 10 – 16 years old; [3] Children under 10 years of age.

Source: Campbell *et al*, 2002.

Table 4.6 **Education Level by Wealth Quartile**

Variable	Wealth Quartile				Mean (all households)	One-way ANOVA, F test
	Lowest 25%	25-50%	50-75%	Top 25%		
Number of household members with no education	1.5[a]	1.5[a]	1.3[ab]	1.0[b]	1.3	*
Number of household members with primary school education	3.5	3.4	3.2	3.5	3.4	NS
Number of household members with secondary school education	1.0[a]	1.7[b]	2.1[bc]	2.6[c]	1.8	***
Number of household members with post-secondary school education	0	0.02	0	0.04	0.02	NS
Sample size	49	50	50	50		

Notes: Education levels are maximum levels attained; Dunnett C test: means followed by a common superscripted letter imply the mean difference is not significant at a 5% level; NS = level of significance is > 5%; * = level of significance is 5%; *** = level of significance is 0.1%.
Source: Campbell *et al*, 2002.

Table 4.7 **Differences in Household Land Holdings (mean acres) Among Wealth Quartiles**

Variable	Wealth Quartile				Overall Mean	One-way ANOVA, F test
	Lowest 25%	25-50%	50-75%	Top 25%		
Dryland acres owned	4.85[a]	6.02[ab]	5.67[ab]	6.74[b]	5.83	*
Garden acres owned	0.37	0.41	0.37	0.56	0.43	NS
Total land owned in acres	5.16[a]	6.48[ab]	6.11[ab]	7.28[b]	6.26	**

Notes: All Scheffe test: means followed by a common superscripted letter imply the mean difference is not significant at a 5% level; NS = level of significance is > 5%; * = level of significance is 5%; ** = level of significance is 1%. The Scheffe test is a multiple comparison test that assumes equal variances of means.

Table 4.8 **Differences in Livestock Ownership Among Wealth Quartiles**

Variable	Wealth Quartile				One-way ANOVA, F test
	Lowest 25%	25-50%	50-75%	Top 25%	
Number of cattle owned	0.27[a]	1.44[b]	3.88[c]	7.37[d]	***
Numbers of goats owned	1.17[a]	2.52[ab]	2.88[b]	7.36[c]	***
Numbers of donkeys owned	0.23[a]	0.32[ab]	1.14[bc]	1.74[c]	***

Notes: All Dunnett C tests: means followed by a common superscripted letter imply the mean difference is not significant at a 5% level; *** = level of significance is 0.1%.
Source: Campbell *et al*, 2002.

Table 4.9 **Differences in Time Use (average hours per day) Among Wealth Quartiles for Males, Females and Children (daily recall data)**

Activity	Wealth Quartile				One-way ANOVA, F test
	Lowest 25%	25-50%	50-75%	Top 25%	
Adult Males					
Garden	0.40^{ab}	0.27^{a}	0.44^{b}	0.50^{b}	**
Dryland crops	2.61	2.50	2.51	2.50	NS
Livestock	0.80^{a}	0.73^{a}	1.10^{b}	1.46^{c}	***
Woodland	0.81^{a}	0.69^{a}	0.65^{a}	0.41^{b}	***
Domestic	4.74	4.94	5.12	4.78	NS
Academic	0.71^{a}	0.69^{a}	0.87^{a}	1.74^{b}	***
Home industries and wages	0.23	0.26	0.37	0.26	NS
Relaxing plus sleeping	13.71^{a}	13.90^{a}	12.91^{b}	12.35^{c}	***
Adult Females					
Gardens	0.70^{a}	0.84^{ab}	0.96^{b}	0.93^{b}	*
Dryland crops	3.07	3.31	3.20	3.25	NS
Livestock	0.00	0.01	0.01	0.01	NS
Woodland	0.89^{a}	0.69^{b}	0.66^{b}	0.49^{c}	***
Domestic	6.95	6.77	7.09	7.18	NS
Academic	0.01^{a}	0.01^{ab}	0.00^{ab}	0.01^{b}	*
Home industries and wages	0.18	0.10	0.20	0.14	NS
Relaxing plus sleeping	12.15^{ab}	12.16^{a}	11.78^{b}	11.80^{ab}	**
Children					
Garden	0.34	0.23	0.24	0.25	NS
Dryland crops	1.33	1.20	1.22	1.07	NS
Livestock	1.22^{ab}	1.09^{a}	1.46^{b}	1.51^{b}	**
Woodland	0.57^{a}	0.43^{ab}	0.39^{b}	0.46^{ab}	**
Domestic	4.34	4.05	4.27	4.41	NS
Academic	4.54	5.18	4.90	5.09	NS
Home industries and wages	0.01	0.01	0.01	0.00	NS
Relaxing plus sleeping	11.62^{ab}	11.77^{a}	11.40^{bc}	11.17^{c}	***
Sample size	697	869	840	791	

Notes: All Dunnett C tests: means followed by a common superscripted letter imply the mean difference is not significant at a 5% level; NS = level of significance is > 5%; * = level of significance is 5%; ** = level of significance is 1%; *** = level of significance is 0.1%
Source: Campbell *et al*, 2002.

Table 4.10 Differences in Cash Expenditures Among Wealth Quartiles (average Z$ per household per year)

Variable	Wealth Quartile			
	Lowest 25%	25-50%	50-75%	Top 25%
Weekly Recall Data (All Expenditures)				
Dryland crops	654	938	1450	2192
Gardening	144	201	276	584
Livestock	247	216	306	907
Woodland use	10	398	63	113
Domestic	5145	6392	8174	15747
Total	6201	8147	10268	19544
Quarterly Recall Data (Major Expenditures)				
Dryland crops	487	802	821	1589
Gardening	41	60	70	137
Livestock	761	611	397	553
Domestic	838	1481	2075	4352
Total	2127	2953	3362	6638

Source: Campbell *et al*, 2002.

Table 4.11 Sectors and Activities for Analysis of Household Livelihoods

Sector	Activities/products
Dryland Agriculture	Maize, sorghum, millet, groundnuts, etc. (rainfed)
Gardens	Tomatoes, green beans, okra, etc. (irrigated)
Livestock Production	Cattle, donkeys, goats, pigs, poultry etc.
Woodland Use	Wood and non-wood products including structural wood, fuelwood, thatch, small animals, fruits, mushrooms, etc.
Domestic	Maintenance of basic household health and nutrition including: preparing and eating meals, housekeeping and construction, attending gatherings, travelling, leisure and sleeping, and education
Wage Labour and Home Industry	Wages from local employment (e.g. domestic and agricultural work) and cash-paying home industries such as carving, brick moulding, fixing bicycle/implements, making household utensils from scrap metal, etc.
Remittances and Gifts	Cash sent from family members not living with the household, and gifts

Source: Campbell *et al*, 2002.

Table 4.12 Gross Cash Income (average Z$ per household per year)

Cash Income Source	Cash Income (Z$)	% Contribution
Remittances	5157	40.8
Wages/Home Industries	3004	23.8
Woodland Sales	383	3.0
Livestock Sales	413	3.3
Garden sales	1211	9.6
Dryland Agriculture	2474	19.6
Overall cash	12642	100

Source: Campbell *et al*, 2002.

Table 4.13 Lower (a) and Upper (b) Bounds of the Coefficient of Absolute Risk Aversion

Wealth Quartile	Value of a	Value of b
Lowest 25%	0.00000351	0.00042061
25-50%	0.00000289	0.00034719
50-75%	0.00000206	0.00024747
Top 25%	0.00000128	0.00015409

Table 4.14 Base Values for Variable Costs, Yields and Prices Used in Household Models

Sector/Wealth Quartile	Variable Costs	Yield	Price
Dryland Agriculture	**Z$/acre**	**kg/acre**	**Z$/kg**
Lowest 25%	172.58	403.21	5.5
25-50%	187.04	387.28	5.5
50-75%	218.08	464.04	5.5
Top 25%	342.36	675.33	5.5
Gardens	**Z$/acre**	**kg/acre**	**Z$/kg**
Lowest 25%	104.77	623.24	6.00
25-50%	186.87	656.55	6.00
50-75%	158.83	762.32	6.00
Top 25%	316.42	1253.12	6.00
Woodlands	**Z$/hour**	**kg/hour**	**Z$/kg**
Lowest 25%	0	8.5	0.25
25-50%	0	8.5	0.25
50-75%	0	8.5	0.25
Top 25%	0	8.5	0.25

Table 4.15 Expert Opinion Rating of Variability of Values of Output of Different Sectors Relative to an Index of 10 for Dryland Agriculture

Sector	Average Index of Variability of Values of Output
Gardens	2.5
Woodlands	1.0
Urban	3.5
Livestock	4.0
Domestic	2.5

Table 4.16 Household Dryland Agriculture Yields, kg/acre

Wealth Quartile	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Lowest 25%	151.84	588.38	150.65	520.58	174.95	10.82	496.75	240.74	200.74	403.21
25-50%	145.84	565.14	144.69	500.01	168.04	10.39	477.12	231.23	192.81	387.28
50-75%	174.74	677.15	173.37	599.11	201.35	12.45	571.69	277.06	231.03	464.04
Top 25%	254.31	985.47	252.32	871.91	293.02	18.11	831.99	403.21	336.22	675.33

Table 4.17 Household Garden Yields, kg/acre

Wealth Quartile	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Lowest 25%	602.02	602.50	603.29	608.65	611.91	581.38	629.56	654.87	617.22	623.24
25-50%	634.20	634.70	635.54	641.18	644.61	612.46	663.20	689.87	650.21	656.55
50-75%	736.37	736.95	737.92	744.48	748.46	711.12	770.05	801.00	754.96	762.32
Top 25%	1210.46	1211.42	1213.02	1223.79	1230.33	1168.96	1265.82	1316.71	1241.02	1253.12

Table 4.18 Household Woodland Yields, kg/hour

Wealth Quartile	State of Nature									
	1	2	3	4	5	6	7	8	9	10
All	7.80	9.02	7.80	8.83	7.86	7.41	8.76	8.05	7.94	8.50

Table 4.19 Household Price Series by State of Nature and Sector, Z$/kg

Sector	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Dryland Agriculture	5.17	5.22	4.78	5.01	4.42	5.04	5.38	4.94	5.12	5.5
Gardens	5.16	5.27	4.14	4.72	3.20	4.80	5.70	4.55	5.01	6.00
Woodlands	0.25	0.25	0.25	0.25	0.24	0.25	0.25	0.25	0.25	0.25

Table 4.20 Values of Domestic Expenditures Funded by Dryland Agriculture and Gardens by State of Nature for the Double Sector Models (Z$)

Wealth Quartile	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Lowest 25%	508.77	1377.64	442.71	1181.53	426.05	210.93	1256.20	653.19	599.09	1093.83
25-50%	839.10	2447.02	736.94	2093.63	724.10	297.55	2208.09	1110.86	1006.99	1902.12
50-75%	1016.53	2852.98	888.45	2443.93	863.59	392.57	2588.17	1324.37	1207.90	2241.83
Top 25%	1910.28	5318.65	1667.95	4557.33	1617.58	749.95	4830.41	2480.56	2265.25	4188.92

Table 4.21 Values of Domestic Expenditures Funded by Dryland Agriculture, Gardens and Woodlands by State of Nature for the Tri-Sector Models (Z$)

Wealth Quartile	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Lowest 25%	795.72	1729.59	725.75	1520.57	709.07	475.84	1597.10	951.20	892.80	1422.11
25-50%	1038.74	2488.33	947.20	2171.44	936.44	550.49	2271.16	1283.90	1190.07	1994.95
50-75%	1310.41	3135.59	1184.03	2731.03	1160.48	690.40	2870.28	1616.60	1500.59	2525.59
Top 25%	2118.13	5458.63	1881.43	4714.10	1833.08	981.03	4978.33	2677.25	2466.01	4349.20

Table 4.22 Sales to Output Ratios by Wealth Quartile

Sector	Wealth Quartile			
	Lowest 25%	25-50%	50-75%	Top 25%
Dryland	0.05	0.10	0.14	0.18
Gardens	0.50	0.54	0.53	0.47
Woodlands	0.16	0.09	0.10	0.05

CHAPTER 5

The Role of Leisure in Household Models of Smallholder Producers

5.1 Introduction

This chapter presents results of an investigation undertaken to address the empirical question of whether it is important to explicitly incorporate leisure in household models of smallholder agricultural producers. The investigation focuses on the seasonality in the opportunity costs of labour. Results of three inquiries into the seasonality in the opportunity costs of labour are presented.

This chapter is of importance to the study since it addresses the question of whether or not leisure should be explicitly represented in household models. Recall from Chapter Two that one school of thought on modelling leisure is based on the premise that the opportunity cost of leisure varies seasonally and leisure should therefore be explicitly modelled in order to capture the opportunity cost of alternative time use. A second school of thought is based on the premise that it may be difficult to distinguish between work and leisure since households use the "leisure" time for household maintenance activities. Accordingly, leisure is hypothesized not to display significant seasonal variability. The second school postulates that leisure does not need to be explicitly represented in household models and can therefore be excluded from the current household analysis.

5.2 Nature of Time Use and Wage Data Collected in the Survey

Household time use data for an adult male, adult female and child residing in each household were collected using a daily recall time frame in six rounds of data collection (Table 4.1). The raw data for time use were collected using a large set of categories that was later aggregated into a small set of time use categories. Table 5.1 provides a listing of the time use activities used in data collection and aggregated time use categories that were constructed during data analysis. For example, time use categories aggregated into "woodlands" included time spent collecting wild fruits, structural woodlands, small animals and wood-fuel. Lobdell and Rempel (1995) indicated that one objective of peasant households is the maintenance of social relationships. In other words, the household is obliged to acquire real resources with which to service social relationships connected with reciprocal exchange, feast day celebrations, and ceremonial events surrounding births, marriages and deaths (Lobdell and Rempel 1995). It is in this light that activities such as gatherings, travelling and entertainment were considered to be basic domestic functions that are geared towards cementing these social relationships[40]. A resting and sleeping time use category was created by summing time spent sleeping, resting and relaxing. This category was specifically designed to capture "leisure" and will be referred to as "sleeping and relaxing". It is assumed that these are the only true leisure activities. The types and nature of wage data collected were documented in Section 4.5.8.

40 Traveling includes trips undertaken to visit relatives in good and bad times. Given the severity of the AIDS scourge, such visits are likely to increase.

5.3 Inquiries into Seasonality in the Opportunity Costs of Labour

A key question regarding labour and household livelihoods concerns whether there are large seasonal variations in the demands for labour. The first school of thought outlined above implies that if leisure varies over time, then it is a choice variable and should be modelled explicitly. Under these conditions new activities or projects that require labour during periods of high demand will be less likely to succeed, while projects introduced during seasons of low labour demand will have a higher probability of success. This logic assumes that the demand for labour displays significant seasonal fluctuations.

An alternate scenario is that households have a suite of labour-using activities that allows them to smooth their labour demands throughout the year. For example, during periods of low labour demand for dryland crops, more time may be spent on gardens, academic endeavours, and woodland collection. This scenario is consistent with the second school of thought outlined above; that is, leisure is constant, and essentially part of the domestic sector.

The degree of seasonal variation in labour demand is investigated using three approaches: (a) analysis of sleeping and relaxing time, (b) analysis of wages, and (c) analysis of substitutability of activities. The results for these analyses are discussed in the following sections.

5.3.1 Analysis of Sleeping and RelaxingTime

If the hypothesis of seasonal variation in labour demand is correct, one would expect to see large and significant differences in the amount of time allocated to sleeping or relaxing between quarters. If the hypothesis of smoothed labour demand is correct, insignificant deviations in sleeping and relaxing time between quarters would be expected.

Table 5.2 shows that during the June through November periods, when dryland crop and livestock activities were less pressing, adults allocated the greatest amounts of time to sleeping and relaxing. In contrast, children spent the most time on sleeping and relaxing during the December through May quarters, when less time was allocated to academic activities. Although the results of tests suggested that not all the means are the same, numerical differences in average time spent on sleeping and relaxing between quarters were not large[41]. In particular, for women and children, the difference between the highest and lowest quarters for mean time spent on sleeping and relaxing was only 0.7 hours/day. For adult males, the difference between the highest and lowest quarters was slightly larger at 1.6 hours/day. The ratio of the standard deviation among wealth groups to the mean[42] as a percentage of the amount of time allocated to sleeping and relaxing for adult females and children was 6.1% while that for adult males was 12.1%. This indicated that there was more variability in time allocated to sleeping and relaxing by

41 Simultaneous confidence intervals around the estimates could not be computed because the observations were repeated between quarters on the same cases.
42 The mean for the four quarters per wealth quartile was calculated as a simple average of the four quarterly means.

adult males compared to adult females and children. However, there did not seem to be important tradeoffs being made between other activities versus sleeping plus relaxing. Instead, the important tradeoffs seemed to be between different types of work. These tradeoffs are analysed in a following section.

5.3.2 Analysis of Wages

Another method of investigating whether or not there are slack labour periods is to compare mean wages between quarters. It is anticipated t that the heavier sleeping and relaxing quarters for adults (June through November) would be associated with decreased demand for labour and decreased wage rates.

Results of statistical tests suggested some statistically significant (1 % level) differences in the mean values of nominal wages between all quarters, with the highest wages occurring in the September to February period (Table 5.3)[43]. However, it was also apparent that wages appeared to be generally increasing over time. This was likely due to inflation, which was estimated to have been approximately 60% per year over the time during which these households were surveyed (Campbell *et al* 2002)[44]. Accordingly the tests were also conducted on deflated, real values[45]. Results showed that with deflated values, there was only statistically significant evidence of unequal mean values between

43 Only combined results for Romwe and Mutangi are presented as analyses showed no significant differences at the 5% level between these two areas.
44 Calculations of the inflation rate were based on changes in the Consumer Price Index (CPI). The rate of inflation in 1999 was calculated to be about 60% (see data in Table C.4).
45 Values were deflated by using linear interpolations of the inflation rate over the course of the year. For example, first quarter values were deflated by 7.5% (i.e. the midpoint between 0 and 15% inflation during the first quarter) while second quarter values were deflated by 22.5% (i.e. the midpoint between 15% and 30% inflation during the second quarter).

quarters at a 5% level. Furthermore, only one quarter, September through November, tended to stand out with a high value (Table 5.3) thus suggesting some evidence of seasonality in the wage rate. The fact that land preparation and planting activities commence in the September to November period might partly account for a tendency towards a higher wage rate in that period. However, this period also coincided with the second highest sleep and relaxation quarters for adults. Although increased labour demands for dryland crops and grazing indicated a degree of seasonality in the wage rate in one of the two labour intensive quarters, the evidence did not show a strong relationship.

5.3.3 Substitutability of Activities

The final approach used to investigate the question of seasonality was an inquiry into the substitutability of activities among household members. In situations where there is smoothing of labour, one would expect that increased time allocation for one activity would displace time previously devoted to another activity. Therefore, one would expect to see negative partial correlations among activities, signifying that more of one activity was undertaken at the expense of another. In contrast, positive correlations between activities would imply that more of an activity could be undertaken while simultaneously increasing time allocated to another undertaking.

For males, females and children, negative correlations dominate the results (Table 5.4)[46]. For example, in the case of males in the March to May quarter, there were negative and

46 Full results of the partial correlation tests are available on the project CD-Rom (Sampurna *et al* 2002).

highly significant partial correlations associated with dryland crop activities, implying that allocation of more time on dryland crops took time away from all other activities. For the few cases where there were positive partial correlations among activities of children, they were mostly recorded between sleep[47] and another activity, implying that more sleep may be required after some tasks.

5.4 Summary of the Inquiry into the Seasonality of the Opportunity Cost of Labour

The results of the three inquiries into the seasonality in the opportunity cost of labour were not exactly the same since they did not produce a defined pattern in the opportunity cost of labour. A comparison of sleeping plus relaxing time relative to wages shows a contradiction in that the quarter having the highest wage does not correspond with the quarters of highest sleep and relaxation time for all three age groups. The expectation is that highest wages would occur during periods of high sleeping and relaxing time. This lack of a defined pattern of results supports the notion that there is no seasonality in leisure.

If results of the analysis into the substitutability of activities are combined with those for sleeping plus relaxing analysis, and wage tests, it is concluded that there was little consistency in evidence to support the view of seasonality of the opportunity cost of labour. Although there was some evidence of seasonality in the opportunity cost of

47 Results pertaining to sleeping and relaxing are not shown in Table 5.4.

labour, the relationship was not strong. Evidence of seasonality in labour demand in one of the two labour intensive quarters was not consistent with full employment. Therefore, any new activity that required labour would have competed with other productive uses of time throughout the year. Leisure appeared to be relatively constant, thus implying that the opportunity cost of leisure was low. Leisure may therefore be considered to be part of the domestic sector, not a choice variable. Results suggested that there was no justification for including leisure as an explicit activity in the risk programming models. Thus leisure, defined as sleeping plus relaxing time, could be modelled implicitly as time that was used for household maintenance activities in household models of smallholder agricultural producers. This approach is followed in the models constructed in this study.

Table 5.1 Time Use Activities Before and After Aggregating

Time Use Activities Used in Data Collection	Aggregated Time Use Activities
Gardens, general agriculture[a]	Gardens
Dryland crops, general agriculture[a]	Dryland crops
Livestock	Livestock
Wild fruits, woodland structural, small animals, woodfuel	Woodland
Domestic, entertainment, gatherings, building/construction, travelling, health, sick, fetching water	Domestic
Academic	Academic
Trading, self-employed, other jobs, others	Home industries and wages
Sleeping, resting, relaxing	Sleeping plus Relaxing

Notes:

a. General agriculture time use was distributed between gardens and dryland crops using proportions based on the contribution of each of gardens and dryland agriculture time use to total agricultural time use (dryland agriculture plus gardens).

Table 5.2 Mean Sleeping and Relaxing Time (hours per day) by Age, Gender, and by Quarter (daily recall data)

Group/Sample Size	March-May	June-August	September-November	December-February	Repeated Measures ANOVA, Greenhouse-Geiser F test
Adult Female	11.7	12.3	12.2	11.6	***
Adult Male	12.4	14.0	13.5	12.9	**
Children	11.8	11.4	11.1	11.8	**
Female Sample Size	981	944	959	948	
Male Sample Size	940	886	868	849	
Child Sample Size	836	815	797	749	

Notes:

a. Repeated measures ANOVA (Analysis of Variance) is used when all members of a random sample are measured under a number of different conditions. As the sample is exposed to each condition in turn, the measurement of the dependent variable is repeated. Repeated measures ANOVA tests the equality of means. The null hypothesis is that of no differences between population means. Repeated measures ANOVA carries the standard set of assumptions associated with an ordinary analysis of variance, extended to the matrix case: multivariate normality, homogeneity of covariance matrices, and independence. Repeated measures ANOVA is robust to violations of the first two assumptions. Sphericity is similar to the assumption of homogeneity of variances in univariate ANOVA. It is a measure of the homogeneity of the variances of the differences between levels, for example, that the variance of the difference between condition 1 and 2 is similar to that between condition 3 and 4. Another way to think of it is that it means that participants are performing in similar ways across the occasions. If the Mauchly test statistic of sphericity is significant, then the Greenhouse-Geisser corrected F value is used. Greenhouse-Geiser F test takes into account the need to adjust both the F test numerator and denominator degrees of freedom in repeated samples (SPSS Online Manual). These notes were added to the table in Campbell et al (2002).

b. ** = level of significance is 5%; *** = level of significance is 1%.

Source: Campbell *et al*, 2002.

Table 5.3 Mean Wage Rates, by Quarter

Wage Rate/Sample Size	March-May	June-August	September-November	December-February	Overall	Repeated Measures ANOVA, Greenhouse-Geiser F Test[a]
Nominal daily wage rate (Z$/day)	58	68	106	104	80	**[b]
Real daily wage rate (February 1999 Z$/day)	48	49	62	45	51	*[b]
N	110	94	76	67	347	

Notes:

a. See table footnote (a) in Table 5.2 on repeated measures ANOVA and the Greenhouse-Geiser F test.

b. * = level of significance is 5%; ** = level of significance is 1%.

Source: Campbell *et al*, 2002.

Table 5.4 Number of Paired Activities with Partial Correlations Negative, Positive, or not Significant at a5% Level (excluding those with sleeping and relaxing)

Age Groups	March-May	June-August	September-November	December-February
Adult Males				
Negative	16	13	15	10
Positive	0	0	0	0
Not Significant	5	8	6	11
Adult Females				
Negative	7	8	8	7
Positive	0	0	0	0
Not Significant	14	13	13	14
Children[a]				
Negative	8	8	7	14
Positive	0	1	0	3
Not Significant	7	12	14	4

Notes:

a. Some values for children were not computable because of insufficient numbers of observations.

Source: Campbell *et al*, 2002.

CHAPTER 6

Calibration of Household Models

6.1 Introduction

This chapter presents a discussion concerning calibration of the empirical models constructed in this study. Model calibration involves testing to see if the model can replicate observed behaviour. In the event that behaviour cannot be replicated, the analyst has to understand why this is so. Calibrated models were used in the subsequent analysis.

6.2 Choice of Measures for Assessment of Best Performing Models

One primary criterion and two secondary criteria are used in this study to evaluate and select best performing models. This study focuses on how and why households allocate resources to competing production activities. Therefore, how well the model predicts production is the primary criterion for the assessment of model fit. The sum of squared deviations between predicted and observed values of output for each sector is used as the primary criterion for assessment of model fit. For example, the sum of squared deviations between solved and observed values of production (DEVSQ) was calculated for the tri-sector models as follows:

$$(6.1) \quad DEVSQ = (DVALUE - DOVALUE)^2 + (GVALUE - GOVALUE)^2 + (WVALUE - WOVALUE)^2$$

where DVALUE, GVALUE and WVALUE are predicted values of production (i.e., model solutions) for dryland agriculture, gardens and woodlands sectors, respectively, while DOVALUE, GOVALUE and WOVALUE are observed values of production for dryland agriculture, gardens and woodlands sectors, respectively. Here value of production is defined in monetary terms (i.e., price times quantity).

This summed square of deviations between the observed and predicted values of output is used as a measure of the overall goodness of fit for the models and can be interpreted as a measure of the error between predicted and observed values of output. In order to express the goodness of fit in relative terms (i.e., relative to observed values), the summed square of deviations is expressed as a ratio. Specifically, the ratio (DEVPCT) of the deviation between predicted and observed values of output relative to the observed value of output is calculated and used as the actual primary criterion measure of model performance. The ratio was derived as follows:

$$(6.2) \quad DEVPCT = (\sqrt{DEVSQ} \,/\, OVALUE) * 100\%$$

where DEVPCT is the derived ratio, DEVSQ is the sum of squared deviations between solved and observed values of production and OVALUE is the total observed value of production for the sectors under consideration. Lower values of the ratio indicate better predictions.

A secondary criterion used in selecting models was a comparison of predicted to observed use of input resources. Resources analysed included acreage devoted to dryland agriculture and gardens and household time allocated to woodlands collection activities. Table 6.1 provides mean observed levels of planted acreage, mean observed endowments, and calculated mean proportional usage of endowments for dryland agriculture and gardens, all by wealth quartile. The table shows that the proportion of fallow land for dryland agriculture was higher than that for gardens. According to expert opinion[48], fallow garden acreage arises from water shortages (e.g., drying up of wells), labour shortages (i.e., labour requirements are high at certain times of the year), cash constraints (e.g., lack of ready cash to purchase seeds) and emergencies (e.g., health or cash problems) that force the households to go to urban areas. Fallow dryland arises from the above factors as well as from a lack of draught animal capacity. Model solutions may not accurately replicate observed values because the impact of emergencies such as AIDS on fallow land were not modelled in the study.

Table 6.2 provides mean observed levels of adult equivalent hours (defined in Section 4.5.5) spent in collecting woodlands products. As shown in Table 6.2, the mean amount of time spent in woodlands activities decreased with increased household wealth.

Another secondary criterion used in model selection was an assessment of predicted to observed levels of consumption and sales for dryland agriculture, gardens and woodlands sectors[49]. This criterion was not considered as important in model selection as the primary criterion, since sales figures played a marginal role in household production and so the deviations were less important. Table 6.3 provides mean total values (price times quantity) for observed levels of sales and total production, as well as sales expressed as a

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48 Professor Bruce Campbell and Witness Kozanayi (Research Assistant) were local experts who had spent considerable time undertaking research in the survey area (see footnote 33).
49 Observed production was calculated as the sum of observed consumption and sales.

percentage of total value of production, for dryland agriculture, gardens and woodlands sectors by wealth quartile. In general, dryland agriculture sales were small relative to production. This is not surprising given that the region has primarily a subsistence economy. For example, across wealth quartiles, an average of between 5.0% and 18.2% of the value of dryland agriculture output was sold (Table 6.3). The proportion of the value of dryland agriculture output sold tended to be higher for wealthier households.

Garden sales were somewhat more significant in relative terms, as approximately 50% of the total value of garden production was sold in each wealth quartile (Table 6.3). However, the absolute values of garden sales were smaller than those for dryland agriculture for wealth quartiles 2-4 (Table 6.3). Wealth quartiles 1 and 4 had the highest and lowest percentages of values of woodlands sales, respectively, thus suggesting a higher dependence by poor households on woodlands activities for generating cash.

6.3 Preliminary Analysis of Models

This section outlines the steps that were taken in the preliminary analysis of the empirical household models. The preliminary analysis was initially done using double sector and tri-sector models with single risk parameters. The preliminary analysis was used to identify best fitting household models. Only results for best fitting models are presented and discussed in later sections.

6.3.1 Analysis of Draught and Labour Wage Rates

Recall from Sections 4.5.6 and 4.5.8 that an average draught hire rate of Z$200/hour and an average labour wage rate of Z$9/hour were calculated using survey data. The markets for hiring draught animals and wage labour in the survey region were thin. This arose from the fact that the survey area represents a subsistence economy. Thus there was a large supply of these resources but little cash available to hire them. In general, thin markets are characterized by a small number of buyers and/or sellers resulting in a scarcity of market transactions. Thin markets are likely to result in distorted prices that may tend to be sticky (or volatile in financial markets) due to demand or supply side shortfalls. Because of uncertainty associated with draught and labour wage rates, sensitivity analysis was conducted. Local experience suggested that few people would be willing to hire draught services at a draught hire rate of Z$200/hour. This derives from a thin demand side market for hiring draught animals. On the other hand, local knowledge suggested that a lot of people would be willing to work at a wage rate of Z$9/hour. Given the high rate of unemployment, the supply of labour at a wage rate of Z$9/hour would be very high. This leads to a thin demand side market for jobs for hired labour. Thus the draught and labour wage hire rates of Z$200/hour and Z$9/hour were thought to be upper bounds. Lower values for these two variables were included in the sensitivity analysis.

Draught hire rates of Z$200/hour, Z$100/hour and Z$50/hour, and labour wage rates of Z$9/hour, Z$5/hour and Z$2/hour were used in sensitivity analysis. Therefore, nine versions of each double sector model with a single risk parameter were run using combinations of draught and labour wage rates outlined above. Results of the sensitivity analysis showed that models of best fit were attained when the draught hire rate was set at Z$50/hour and that different levels of the wage rate did not matter because very little labour was hired. Thus, a draught hire rate of Z$50/hour and a wage rate of Z$9/hour were used in solving empirical household models.

6.3.2 Analysis of Prices

Prices collected during the survey were mainly market prices based on local transactions. There were no national markets for gardens and woodlands sectors. Gardens and woodlands sales were mainly local in nature and the amount of surplus that could be absorbed by the local markets was therefore limited. On the other hand, there was a well functioning national market for dryland crops such as maize. Thus households could sell all surplus maize on the national market.

In the case of dryland agriculture, it was reasonable to assume equality of market and consumption prices since there was a well functioning national market for maize where they could dispose of all surplus maize. One challenge faced was to estimate the true value of consumption for gardens and woodlands. Given that markets for gardens and woodlands were thin, it was thought that market prices likely did not reflect consumption values. Sensitivity analysis was carried out to determine the appropriate level for gardens and woodlands consumption prices. Best fitting double sector models with single risk parameters were attained when garden consumption prices for all wealth quartiles were set at a lower level; that is, 50% of the surveyed garden market prices. Best fitting tri-sector models with single risk parameters were attained when woodlands consumption prices were set at 50% of the surveyed woodlands market prices for wealth quartiles 1 and 2, and 60% and 85% respectively for wealth quartiles 3 and 4. It is not clear why higher wealth class models fit better with higher woodlands consumption values. It is possible that lower wealth quartiles may become more satiated with any wood products at higher levels, thereby decreasing their consumption value. This increased satiation could occur because lower wealth levels do not have as diverse a consumption basket of woodlands products as for higher wealth classes. It could also be that the opportunity cost of labour for woodlands production increases with wealth given that woodlands appeared to be a smaller activity (time-wise) for the wealthier households (Table 6.2). In the next chapter, results will be presented at 50% garden consumption prices and the respective woodland consumption prices that produced the best results.

6.3.3 An Outlier State of Nature

Solutions obtained for some of the tri-sector models tended to be "sticky" in terms of being very stable. However, when changes to solutions did occur, they tended to be extreme in nature. For example, a change in the woodlands consumption price would result in the solution changing from including woodland hours that are significantly greater than observed to a solution with practically zero woodland hours. Moreover, solutions for the tri-sector models that tended to be sticky were not as good in terms of objective function value as best solutions attained by the best fitting double sector models. In going from two to three sectors, the feasible set increased in size and the same optimal solution from the two-sector model was still feasible. Despite that fact, the optimal solutions for the three-sector models tended to be "worse" in terms of utility than for the two-sector models. It became apparent after trying to force (through added constraints) the model to shift labour to dryland agriculture that the sticky solutions were arising from an outlier state of nature; i.e., state of nature 6. The addition of these extra constraints led to infeasible solutions. State of nature 6 had the lowest yields for all three sectors (Tables 4.16-4.18). The extreme nature of the poor yields for state of nature 6 was making it difficult for households to meet cash requirements necessary to fund domestic expenditures.

The structure of the model used in this study is such that it implicitly assumes that all 10 states of nature have an equal chance of occurrence. The fact that the model was having difficulties mimicking actual behaviour suggested that households may not have viewed the low yields for state of nature 6 as having a one in ten chance of occurring, but rather as an "outlier" occurrence. This essentially meant that this state of nature was being given too much weight in terms of influencing household decisions within the model. Therefore, the models were also run with the outlier removed. To remove the outlier, average yields calculated over the 10 states of nature by wealth quartile were used to replace actual values for the state of nature outlier.

A comparison of results with and without the state of nature outlier was undertaken. The ratio of the deviation between solved and observed values of production to the observed value of production (DEVPCT) was generally lower for models without the state of nature outlier (Table 6.4). An analysis of the results based on the primary criterion measure for assessment of model performance showed that models without the state of nature outlier generally performed better than models with the state of nature outlier (Table 6.4). This result held for both double sector models and tri-sector models. The one exception was found in wealth quartile 3 where single risk parameter tri-sector models with the state of nature outlier performed better than tri-sector models without the state of nature outlier. Therefore, a decision was made to base the results on models without the state of nature outlier since they were generally performing better than the models with the state of nature outlier.

6.3.4 Model Resolution Issues

There was a problem when going from double to tri-sector models in that in some cases a "worse" solution was obtained with the three sectors in terms of expected utility, even though the corresponding "better" double sector solution was still feasible. This led to an investigation of optimality tolerance in GAMS. Optimality tolerance is a parameter in GAMS that controls the solver in terms of when to stop searching for a better solution. In particular, the optimization procedure stops once the degree of potential improvement from the current solution is less than the specified optimality tolerance. The default optimality tolerance value in GAMS is $1x10^{-6}$. As a result of the investigation, it was decided to decrease the acceptable optimality tolerance to $1x10^{-9}$, forcing GAMS to search further for solutions. This, combined with scaling[50], solved the problem. The scaling of the variables and constraints, i.e. the units of measurement used for the variables and constraints, determine the relative size of the derivatives and of the function values and thereby also the search path taken by the algorithm (CONOPT Manual). The objective functions for the tri-sector models were scaled (multiplied) by 1000.

6.5 Implications of the Results of Model Calibration

The model calibration exercise identified best performing model versions for both double sector and tri-sector household models. Table 6.5 provides a summary of calibration results on consumption prices and hire rates for labour and draught animals. Results of best performing models are discussed in full in the next chapter.

50 Scaling results in all the coefficients associated with a variable or equation being divided by the scaling factor (McCarl GAMS Related Software Version 0, http://ageco.tamu.edu/faculty/mccarl/gamsstuf/gamstip.htm). Scaling may involve multiplication by the scaling factor. Scaling does not affect the solution output but only changes the marginal values. There is a mathematical justification for saying that scaling doesn't matter, that is; if the entire objective is scaled up or down by the same amount, it has no effect on the solution. There is also a behavioural justification, that is; utility functions are ordinal and can be scaled up or down by linear transformations.

Table 6.1 Mean Observed Land Endowments and Planted Acreages Per Household by Sector and Wealth Quartile

Wealth Quartile	Dryland Agriculture			Gardens		
	Observed Area Planted (Acres)	**Endowment (Acres)**	**Ratio of Observed Area Planted to Endowments (%)**	**Observed Area Planted (Acres)**	**Endowment (Acres)**	**Ratio of Observed Area Planted to Endowments (%)**
Lowest 25%	2.7	4.9	56.0	0.4	0.5	79.5
25-50%	3.8	6.1	62.9	0.3	0.5	72.1
50-75%	3.6	5.8	63.0	0.4	0.5	81.3
Top 25%	4.6	6.8	67.4	0.4	0.6	70.0

Table 6.2 Mean Observed Annual Adult Equivalent Hours Allocated to Woodlands per Household, by Wealth Quartile

Wealth Quartile	Adult Equivalent Hours
Lowest 25%	990.1
25-50%	950.5
50-75%	919.6
Top 25%	748.6

Table 6.3 Mean Total Sales and Production Values[a] by Sector and Wealth Quartile, in Z$

Sector	Activity	Wealth Quartile							
		Lowest 25%		25-50%		50-75%		Top 25%	
		Z$	% Sales to Total Sector Production	Z$	% Sales to Total Sector Production	Z$	% Sales to Total Sector Production	Z$	% Sales to Total Sector Production
Dryland Agriculture	Sales	303.57	5.0	841.61	10.4	1256.86	13.5	3113.02	18.2
	Production	6019.33		8115.40		9290.10		17141.50	
Gardens	Sales	719.54	49.5	708.55	54.2	1049.26	52.8	1533.36	47.0
	Production	1453.79		1306.28		1987.81		3264.64	
Woodlands	Sales	339.52	15.7	165.95	9.2	201.30	10.0	104.36	5.4
	Production	2169.38		1803.70		2015.68		1938.26	

Notes:

a. Base prices for state of nature 10 (Table 4.14) were used for valuing sales and production. Total production value was equal to the sum of sales and consumption values.

Table 6.4 **Comparison of Values and Percentages Based on the Primary Measure for Assessment of Best Performing Models With and Without State of Nature Outlier[a] by Type of Model and Wealth Quartile**

Model	Unit/ Predicted Percentage	Wealth Quartile							
		Lowest 25%		25-50%		50-75%		Top 25%	
		State of Nature Outlier							
		With	Without	With	Without	With	Without	With	Without
Double Sector, Single Risk Parameter	DEVROOT[b], Z$	683.9	482.3	2241.8	41.4	68.0	22.6	1854.3	334.8
	% DEVROOT to Observed Output Value	9.2	6.5	23.8	0.4	0.6	0.2	9.1	1.6
Double Sector, Two Risk Parameters	DEVROOT, Z$	643.9	482.3	2241.8	138.0	68.0	53.5	1854.3	120.4
	% DEVROOT to Observed Output Value	8.6	6.5	23.8	1.5	0.6	0.5	9.1	0.6
Tri-sector, Single Risk Parameters[c]	DEVROOT, Z$	480.0	462.9	3807.4	598.9	606.6 (606.9)	2342.3 (606.6)	2676.0 (2676.0)	2429.0 (1799.0)
	% DEVROOT to Observed Output Value	5.0	4.8	34.0	5.3	4.6 (4.6)	17.6 (4.6)	12.0 (12.0)	10.0 (8.1)
Tri-sector, Three Risk Parameters[c]	DEVROOT, Z$	6896.9	550.9	5115.9	630.5	608.3 (634.4)	2342.3 (609.6)	2676.0 (2676.0)	2436.0 (1799.4)
	% DEVROOT to Observed Output Value	71.5	5.7	45.6	5.6	4.6 (4.8)	17.6 (4.6)	12.0 (12.0)	10.9 (8.1)

Notes:

a. State of nature 6 yield values were the lowest and was therefore considered to be an outlier state of nature. Models with the state of nature outlier were based on actual yield values for state of nature 6. To remove the outlier, average yields calculated over the 10 states of nature by wealth quartile were used to replace actual values for state of nature 6.

b. DEVROOT = square root of the sum of squared deviations between the observed and predicted values of output.

c. Recall from Section 6.3.2 that best performing models for wealth quartile 3 and 4 were respectively at 60% and 85% woodlands consumption values. The results for these percentages of woodlands consumption values are in parentheses.

Table 6.5 Summary of Calibration Results

Sector	**Wealth Quartile**			
	Lowest 25%	**25-50%**	**50-75%**	**Top 25%**
Dryland Agriculture Consumption Price [a], %	100	100	100	100
Garden Consumption Price, %	50	50	50	50
Woodlands Consumption Price, %	50	50	60	85
Labour Wage Rate, Z$/hour	9	9	9	9
Draught Hire Rate, Z$/hour	50	50	50	50

Notes:

a. Consumption prices as a percentage of the calculated sales price series.

CHAPTER 7

Model Predictions and Risk Preferences

7.1 Introduction

The purpose of this chapter is to report results regarding risk preferences and model predictions for the best fitting double sector and tri-sector household models. This chapter also presents comparisons of the results of best fitting models to assess the impact of changing the number of sectors and risk parameters included in models. Results for double sector models are presented first, followed by those for tri-sector models.

7.2 Double Sector Model Results

Results for double sector models are based on estimated risk parameter(s) that produced the lowest values of the primary criterion measure of model performance; that is, the ratio of the deviation between predicted and observed values of output, and the observed value of output (equation 6.2). The results reported are for state of nature 10 (i.e., the base state). Results for best performing double sector (and tri-sector) models are based on advanced basis solutions[51].

51 The use of an advanced basis, versus a re-initialized basis, is discussed in Chapter 3, Section 3.3.5. Results suggested that in a majority of the cases, models based on an advanced basis performed as well or better than those based on a reinitialized basis in terms of the selected criteria of model performance identified in Section 6.2.

7.2.1 Risk Preferences for Double Sector Models

This section presents results for the investigation of risk preferences for double sector models, for both single and multiple risk parameter estimation. Figure 7.1 shows changes in the value of the deviations between predicted and observed values of output with changes in the value of the risk parameter for double sector models with a single risk parameter[52]. The figure for changes in the deviations between predicted and observed values of output for double risk parameter models was multi-dimensional in shape and therefore difficult to depict. The grid search for the value of the risk parameter that minimized the sum of squared deviations between the predicted and observed values of output for double risk parameter models was repeated multiple times using the "loop" command in GAMS.

Single risk parameter model results showed that representative households in wealth quartiles 2, 3 and 4 displayed changing risk preferences (Figure 7.1). Single and double risk parameter models for wealth quartile 1 produced constant sums of squared deviations between predicted and observed values of output regardless of the value of the risk parameter(s). A constant value of the sum of squared deviations between predicted and observed values of output suggested that optimal predicted household behaviour was not influenced by different levels of risk aversion. Thus households in wealth quartile 1 may

52 Values of risk parameters for single risk parameter models for wealth quartiles1 and 4 were increased by 0.0001 at each step while those for wealth quartiles 2 and 3 were increased by 0.00015. The size of the steps was calculated based on an objective of covering the range between the lower and upper bounds of the coefficient of absolute risk aversion (Table 4.13). The value of the risk parameter therefore increases with the number of iterations.

have been constrained (with respect to production and consumption) to the point that risk preferences did not influence their decisions. The households in wealth quartiles 2-4 were less constrained by virtue of having more resources, and therefore household risk preferences influenced production and consumption decisions.

For each wealth quartile, Table 7.1 provides values of the coefficients of absolute and relative risk aversion for single and double risk parameter models. Values of the coefficient of absolute risk aversion were calculated using values of the risk parameter associated with the minimum value of the sum of squared deviations between solved and observed values of production (see Appendix A1). The ranges of values for the coefficients of absolute and relative risk aversion in Table 7.1 indicate that none of the single risk parameter models for wealth quartiles 2-4 depicted unique risk preferences. The results suggested that rather than a single level, a range of risk aversion levels would be consistent with observed household behaviour. Double risk parameter models for wealth quartiles 3 and 4 depicted unique risk preferences for both garden and dryland agriculture sectors.

Aside from the indeterminate results for wealth quartile 1, values of absolute coefficients of risk aversion for single and double risk parameter models generally show the expected trend, where higher wealth quartiles have lower risk aversion. Wealth quartiles 2 and 3 had similar risk aversion levels while wealth quartile 4 was significantly lower. Values of the coefficient of relative risk aversion for single risk parameter models for wealth quartiles 2-4 were between 4.05 and 5.88.

An examination of the values of the coefficients of absolute and relative risk aversion for double risk parameter models showed that households in wealth quartiles 2 and 3 displayed greater risk aversion for the garden sector as compared to dryland agriculture (Table 7.1). Greater risk aversion for gardens exhibited by these households may be attributable to the fact that gardens are fundamental to a subsistence livelihood activity and therefore constitute a greater necessity for household life. In the case of wealth quartile 4, households displayed greater risk aversion for the dryland agriculture sector, suggesting that this sector is deemed to be vital to household livelihoods.

Values of the coefficients of relative risk aversion by sector for double risk parameter models were between 3.38 and 6.48 for gardens while those for dryland agriculture were between 0.95 and 9.15. Thus some of the values of the coefficient of relative risk aversion were greater than the upper bound of the empirical values suggested by Hardaker *et a*l (1997). Little and Mirrlees (1974) suggested that the coefficient of relative risk aversion will be close to 2 while Hardaker *et a*l (1997) suggested a range of 0.5-4.0. Coefficients of relative risk aversion for wealth quartiles 2 and 4 in double risk parameter models for gardens were within the range of empirical estimates. The fact that empirical values of the coefficients of relative risk aversion attained for some wealth quartiles in both single and double risk parameter models was greater than the upper bound of empirical estimates meant that the households appeared to be more risk averse than would be suggested from previous literature. One possible explanation for this is that the range of empirical estimates was mainly based on data obtained from developed economies where higher incomes may lead to lower risk aversion.

7.2.2 Predicted Results for Double Sector Models

Table 7.2 provides results for single and double risk parameter models (i.e., dryland agriculture and garden activities). The results are used to assess the performance of double sector models with different numbers of risk parameters.

7.2.2.1 Deviation Between Predicted and Observed Values of Output

Generally, the double sector models were relatively accurate in terms of reproducing observed values (Table 7.2). Double sector models for wealth quartile 1 had the largest ratio of the deviation between predicted and observed values of output to the observed value of output (i.e., 6.5%) while the ratios for the other wealth quartiles ranged from 0.2% to 1.6%.

7.2.2.2 Dryland Agriculture

For all dryland agriculture results, there was little difference between single and double risk parameter models within a given wealth group. Predicted acres of dryland agricultural production in single and double risk parameter models were between 94.9% and 101.4% of observed dryland agriculture acreage. Predicted kilograms of dryland agricultural consumption were between 79.3% and 88.6% of observed value. Predicted kilograms of dryland agricultural sales in double sector models were between 136.7% and 329.9% of observed dryland agriculture sales. These high sales figures for dryland agriculture were not considered to be worrisome given that observed sales values for dryland agriculture were only between 5.0% and 18.2% of observed dryland agriculture production values for all wealth quartiles (Table 6.3). Thus dryland agriculture sales values were relatively insignificant compared with total production values. As a result, small deviations from observed values when measured in absolute terms correspond to large percentage deviations. This is somewhat confirmed by the fact that the percentage deviation decreases with increased dryland agriculture sales.

7.2.2.3 Gardens

Results for garden activities for wealth quartile 1 were all greater than observed values while results for the other wealth quartiles provided a better fit (Table 7.2). Predicted acres of garden production were between 93.5% and 125.7% of observed garden acreage for single and double risk parameter models (Table 7.2). Survey data on garden land use suggested that households were planting between 56.0% and 67.4% of observed garden acreage endowments (Table 6.1). Expert opinion confirmed the existence of fallow garden land for some households (Section 6.2). For all garden results, there was little difference between single and double risk parameter models within a given wealth group. Predicted kilograms of garden consumption were between 97.8% and 125.7% of observed garden consumption for single and double risk parameter models. Predicted garden sales were between 93.5% and 125.8% of observed garden sales for single and double risk parameter models. The garden sales constraint (equation 3.7) limited garden sales to be no greater, proportionally, than the observed ratio of sales to production. Given that this constraint was binding, an increase in predicted output automatically implied an increase in consumption and sales.

7.3 Tri-Sector Model Analysis

The next phase of the analysis was to solve tri-sector models (i.e., models including dryland agriculture, garden and woodlands activities). The feasible set for the tri-sector models was larger than that for the double sector models given that there was an increase in resources available (e.g., labour). Domestic expenditures were also higher in the tri-sector models. Tri-sector models were considered to be more complete by virtue of having an increased set of endogenous variables compared to double sectors models. The downside was that increasing the number of endogenous variables also introduced greater challenges in terms of modelling. For example, "woodlands" was a large and complex basket of diverse activities that were aggregated for the purpose of this analysis. This increased the degree of difficulty in modelling woodlands as a single sector. The analysis pertaining to the woodlands sector was a demonstration of the challenges encountered in modelling aggregate sectors. Tri-sector models were constructed using parameters associated with best fitting double sector models as highlighted in Section 6.3.

7.3.1 Risk Preferences for Tri-sector Models

This section presents results of risk preferences for tri-sector models for single and multiple risk parameter estimation. For all wealth quartiles, the sum of squared deviations between predicted and observed values of output for single risk parameter tri-sector models changed as the risk parameter was varied (Figure 7.2). This result indicated that households in all wealth quartiles had changing risk preferences in the single risk parameter tri-sector models. Risk preferences in single risk parameter models were more distinct at lower wealth levels as exemplified by distinct dips at points of the minimized deviations between predicted and observed values of output for wealth quartiles 1 and 2 (Figure 7.2). Risk attitudes for single risk parameter models for wealth quartiles 3 and 4 were non-distinct since the graphs flattened out over a large range of values of the risk parameter. As with the double sector models, the figure for changes in the deviations between predicted and observed values of output for multiple risk parameters in the case of the tri-sector models was multi-dimensional in shape and therefore difficult to depict. The grid search for the value of the risk parameter that minimized the sum of squared deviations between the predicted and observed values of output for triple risk parameter models was repeated multiple times using the "loop" command in GAMS. As in the single risk parameter models, for all wealth quartiles, the sum of squared deviations between predicted and observed values of output for triple risk parameter models changed as the risk parameter was varied.

For each wealth quartile, Table 7.3 provides values of the coefficients of absolute and relative risk aversion for single and triple risk parameter models. For single risk parameter models, wealth quartiles 1 and 4 had similar levels. Both of these groups displayed significantly lower levels of risk aversion than wealth quartiles 2 and 3. The results for wealth quartile 1 were contrary to expectations but may perhaps be explained, again, by limited choices that may prevent risk aversion from being exhibited. There was no defined pattern of changes in values of the coefficient of absolute risk aversion with wealth for triple risk parameter models.

Coefficients of absolute and relative risk aversion for single risk parameter models for wealth quartiles 1-3 were unique. The results for single risk parameter models for wealth quartile 4 suggested that rather than a single level, a range of risk aversion levels would be consistent with observed household behaviour. All coefficients of relative risk aversion for gardens, dryland agriculture and woodlands were unique in triple risk parameter models.

The values of the coefficients of relative risk aversion for single risk parameter models were between 2.38 and 8.16 while those for triple risk parameter models were between 1.26 and 8.85. An examination of the values of the coefficients of absolute and relative risk aversion for triple risk parameter models showed that the woodlands sector displayed the greatest risk aversion for households in wealth quartile 1, followed by gardens (Table 7.3). Dryland agriculture was the most risk averse sector for households in wealth quartile 2, followed by gardens. In the case of wealth quartile 3, woodlands was the most risk averse sector, followed by dryland agriculture. Woodlands was the most risk averse sector for wealth quartile 4, with gardens and dryland agriculture displaying identical risk preferences. Results suggested that woodlands was the most risky sector for households in wealth quartiles 1, 3 and 4. Again, higher risk aversion to woodlands displayed by households in the poorest wealth quartiles could be attributed to their dependence on that sector for subsistence. In the case of the wealth quartiles 3 and 4, dependence on the woodlands sector is low and so woodlands may have been seen as a more risky sector on which to rely.

Apart from the coefficient of relative risk aversion for dryland agriculture for wealth quartile 2, all values of the coefficient of relative risk aversion for wealth quartiles 1 and 2 in single and triple risk parameter models were within the range of empirical estimates of 0.5-4.0 given by Hardaker *et al* (1997). All values of the coefficient of relative risk aversion for single and triple risk parameter models for wealth quartiles 3 and 4 were greater than the upper bound of the empirical estimates. The fact that the empirical values of the coefficient of relative risk aversion attained for wealth quartiles 3 and 4 were greater than the upper bound of empirical estimates meant that the households appeared to be more risk averse than would have been otherwise expected. Again, as in the case for the double sector models, the range of empirical estimates was mainly based on data obtained from developed economies where higher incomes may lead to lower risk aversion.

7.3.2 Predicted Results for Tri-sector Models

Table 7.4 provides results for single and triple risk parameter models. The results are used to assess the performance of tri-sector models with different numbers of risk parameters.

7.3.2.1 Deviation Between Predicted and Observed Values of Output

In general, solutions for the tri-sector models were reasonably accurate in predicting observed behaviour (Table 7.4). Tri-sector models for wealth quartile 4 had the largest ratio of the deviation between predicted and observed values of output to the observed value of output (i.e., 8.1%) while the ratio for the other wealth quartiles ranged from 4.6% to 5.7%.

7.3.2.2 Dryland Agriculture

For all dryland agriculture results there was little difference between single and triple risk parameter models within a given wealth group. Predicted acres of dryland agricultural production were between 93.3% and 97.2% of observed dryland agriculture acreage in single and triple risk parameter models. Predicted kilograms of dryland agricultural consumption were between 79.7% and 89.0% of observed values in single and triple risk parameter models. Predicted kilograms of dryland agricultural sales were between 121.2% and 330.8% of observed dryland agriculture sales in single and triple risk parameter models. As was the case for the double sector models, these high sales figures were not considered to be worrisome given that dryland agriculture sales values were relatively insignificant compared with total production values (Table 6.3).

7.3.2.2 Gardens

For all garden results, there was little difference between single and triple risk parameter models within a given wealth group. Model results indicated that all wealth groups used all of the garden acreage endowment. Predicted acres of garden production were between 123.0% and 142.8% of observed garden acreage for single and triple risk parameter models. Tri-sector models may not have accurately predicted garden production acreage because the impact of emergencies (e.g., AIDS) on fallow land was not modelled. Predicted kilograms of garden consumption in single and triple risk parameter models were between 122.5% and 142.7% of observed garden consumption. Predicted garden sales in single and triple risk parameter models were between 123.5% and 142.9% of observed garden sales. The garden sales constraint (equation 3.7) limited garden sales to be no greater, proportionally, than the observed ratio of sales to production. Given that this constraint was binding, an increase in predicted output automatically implied an increase in sales and consumption.

7.3.2.3 Woodlands

For woodland results, there was little difference in single and triple risk parameter models within a given wealth group. Predicted woodlands production time was between 61.3% and 105.3% of observed woodlands production hours for single and triple risk parameter models. Wealth quartiles 1 and 4 had the highest and lowest predicted percentages of woodlands production time (i.e., 105.3% and 61.3%), respectively, in single and triple risk parameter models. Wealth quartile 4 had the lowest mean observed annual adult equivalent hours allocated to woodlands production per household (Table 6.2). Wealth quartiles 1 and 4 had the highest and lowest predicted percentages of woodlands consumption in single and triple risk parameter models, i.e., 102.5% and 47.5% of observed woodlands consumption, respectively. The results suggested that the poorest households allocated more time to woodlands production and showed a higher dependence on woodlands for consumption. Indeed, the richest quartile had approximately half of the consumption and labour allocation that all other groups exhibited. As such, the role of woodlands in wealth quartile 4 was quite different, and less significant, compared to other wealth groups, and the model was not able to accurately predict this behaviour.

Single and triple risk parameter models predicted woodlands sales kilograms perfectly; that is, 100% of observed woodlands sales. However, this result was predetermined given that the woodlands sales constraint was set to be less than or equal to observed sales levels (equation 3.8). Wealth quartiles 1 and 4 also had the highest and lowest quantities (kilograms) of woodlands sales, thus suggesting a higher dependence by poor households on woodlands activities for generating cash.

7.4 Comparison of Results for Double Sector and Tri-sector Models with Single Risk Parameters

This section compares results for double sector and tri-sector models with a single risk parameter in order to address the research issue of whether results of partial sector models are improved by increasing the number of sectors being modelled. For all of the following analysis in this section, single risk parameter models were used thus only varying the effect of numbers of sectors. This approach was also warranted because there was little difference between single and multiple risk parameter results within a given wealth group.

Tables 7.1 and 7.3 provide values of the coefficient of absolute and relative risk aversion for double sector and tri-sector models. Concentrating on the single risk parameter results, a number of differences were evident. First, tri-sector models exhibited more distinct estimates of risk preferences than the ranges produced by double sector models. This result was likely because in tri-sector models there were more choices possible, and therefore more opportunities for distinct risk preferences to be expressed. Second, for wealth quartiles 3 and 4, the values of relative risk aversion were significantly larger in the tri-sector models. However, absolute values did not display as large a difference. Finally, it can be seen that for wealth quartile 1 in the double sector model, risk preferences were indeterminate, contrary to results for wealth quartile 1 in the tri-sector model where risk preferences were exhibited, but with relatively low risk aversion. In this case, it is conjectured that a combination of model constraints and a lack of choices facing these poorest households may combine to create this indeterminate result.

Table 7.5 presents results for assessing the performance of double sector and tri-sector models. A comparison of the results for double and tri-sector models showed that for wealth quartile 1, the tri-sector model performed better in terms of DEVROOT. Conversely, for wealth quartiles 2-4, double sector models performed better than tri-sector models, although performance for all the models was good. These results suggested that for wealth quartile 1, adding in the woodlands sector created a more realistic depiction of their choices. Conversely, for the other wealth quartiles, problems associated with the woodlands sector being an aggregation of a vast range of goods may have outweighed the benefits associated with creating a more complete picture.

For dryland agriculture, results for double and tri-sector models were not significantly different. Predicted acres of dryland agricultural production in double sector and tri-sector models were between 97.2% and 100.2% of observed dryland agriculture acreage. Predicted kilograms of dryland agricultural consumption were between 79.3% and 89.0%

of observed values. Tri-sector models for wealth quartiles 2-4 performed marginally better than double sector models in predicting dryland agriculture sales. However, as stated in Section 7.2.2.2, high sales figures for dryland agriculture were not considered to be worrisome given that observed sales values for dryland agriculture were only between 5.0% and 18.2% of observed dryland agriculture production values for all wealth quartiles.

For gardens, results for double and tri-sector models were also similar. Double sector models for wealth quartiles 2-4 performed better than the tri-sector models in predicting garden acreage, consumption and sales. For example, predicted acres of garden production in the double sector and tri-sector models for wealth quartile 2 were 101.9% and 138.7% of observed garden acreage, respectively. Results for both double and tri-sector models showed that households were using all of the garden acreage endowment. As stated in Section 7.2.2.3, the garden sales constraint (equation 3.7) limited garden sales to be no greater, proportionally, than the observed ratio of sales to production. Given that this constraint was binding, an increase in predicted output automatically implied an increase in consumption and sales. In contrast to these results, wealth quartile 1 double and tri-sector model results for gardens were similar.

Based on the above analysis, the results appear to be inconclusive. In reality, household models with more sectors are deemed to be more complete than those with fewer sectors. Part of the differences in results between double sector and tri-sector models could be attributed to the difficulty in modelling woodlands as a single sector. As stated above, "woodlands" was a large and complex basket of diverse activities that were aggregated for the purpose of this analysis. It is possible that results may differ depending on the number of sectors modelled provided that additional sectors can be modelled completely.

7.5 Summary of Results

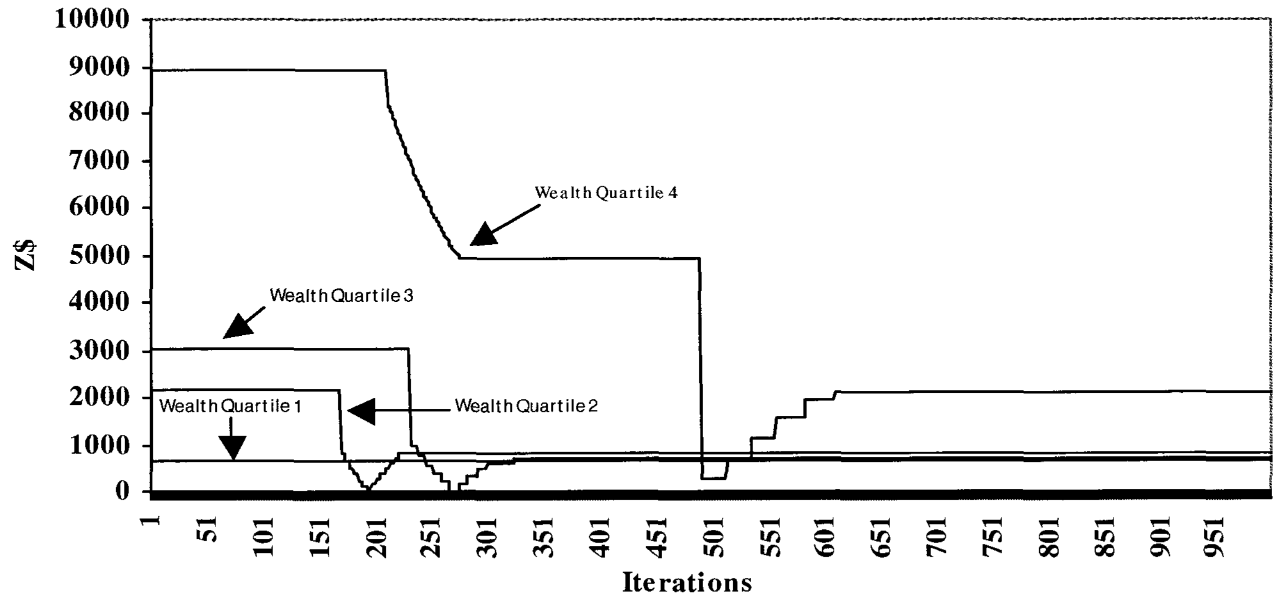
In general, the models did a good job in replicating observed behaviour, which gave some confidence in the derived risk preferences derived. In all cases where there were determinate results regarding risk preferences (i.e. all models except for wealth quartile 1 with two sectors), wealth groups generally displayed high levels of risk aversion when compared to ranges suggested in the literature. Given that the literature was largely based on research from developed country studies, the high values derived in this study are deemed to be plausible in the context of the low incomes in the study area.

All models were relatively accurate in terms of reproducing observed values. For double sector models, ratios of the deviation between predicted and observed values of output were in the range of 0.2% to 6.5%. For triple sector models, the range was 4.6% to 8.1%. Results improved for wealth quartile 1 with the addition of the woodlands sector, but decreased the overall performance for the other wealth groups.

There was little difference in results between single and multiple risk parameter models for a given wealth group. The results therefore suggested that there was no advantage in pursuing multiple risk parameter models. This result could, however, be a reflection of the modelling environment which could prevent higher degrees of modelling resolution from showing positive results.

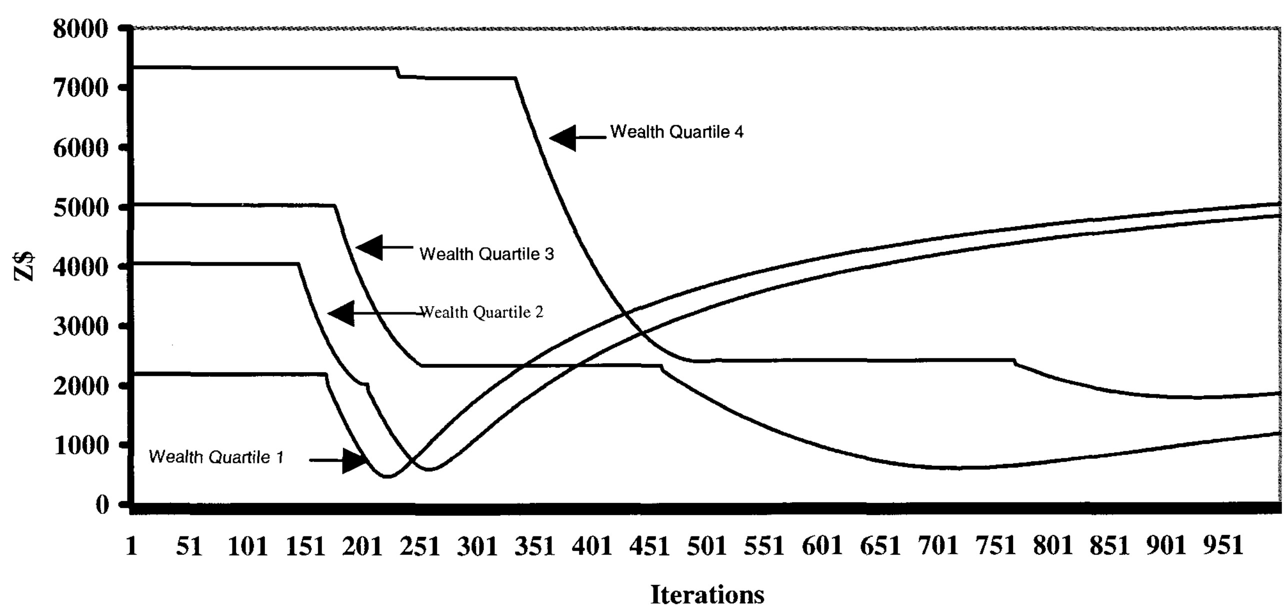
Finally, the comparison of double sector and tri-sector household models produced inconclusive results. For wealth quartile 1, tri-sector models (which include woodlands) performed better than two sector models, likely because of the important role played by woodlands in poor households. For wealth quartiles 2 through 4, where woodlands play a smaller role, the benefits of adding an additional sector seemed to be outweighed by the problems associated with the complexity in modelling the additional woodlands sector.

Figure 7.1 **Deviations Between Predicted and Observed Values of Output for Double Sector Models With a Single Risk Parameter, Z$**



Note: The x axis in this graph refers to iterations which correspond to different risk parameter values for different wealth groups. As such the risk aversion levels in the figure are not comparable. Refer to Table 7.1 for comparisons.

Figure 7.2 **Deviations Between Predicted and Observed Values of Output for Tri-sector Models With a Single Risk Parameters, Z$**



Note: The x axis in this graph refers to iterations which correspond to different risk parameter values for different wealth groups. As such the risk aversion levels in the figure are not comparable. Refer to Table 7.3 for comparisons.

Table 7.1 Coefficients of Absolute and Relative Risk Aversion for Double Sector Models

	Single Risk Parameter		Double Risk Parameters			
	Gardens and Dryland Agriculture Sectors Combined		Gardens		Dryland Agriculture	
	COARA[a]	CORRA[b]	COARA	CORRA	COARA	CORRA
Lowest 25%	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate
25-50%	0.000105 – 0.000106	4.05 – 4.09	0.000102>>	3.93>>	$2.47X10^{-5}$ – 0.000238	0.95-9.15
50-75%	0.000105-0.000107	5.66-5.74	0.00012>>	6.48>>	$8.47X\ 10^{-5}$	4.56
Top 25%	$6.63X10^{-5}$-$6.8X10^{-5}$	5.74-5.88	$3.9X10^{-5}$	3.38	$8.22X10^{-5}$>>	7.11>>

Notes:
a. COARA = Coefficient of Absolute Risk Aversion.
b. CORRA = Coefficient of Relative Risk Aversion.
>> most risk averse

Table 7.2 Results for Best Performing Double Sector Models

Predicted Variable	Unit/ Predicted Percentage	Number of Risk Parameters							
		Single	Double	Single	Double	Single	Double	Single	Double
		Wealth Quartile							
		Lowest 25%		25-50%		50-75%		Top 25%	
DEVROOT[a]	Z$	482.3	482.3	41.4	138.0	22.6	53.5	334.8	120.4
	% DEVROOT to Observed Output Value	6.5	6.5	0.4	1.5	0.2	0.5	1.6	0.6
Dryland Agriculture Acreage	Acres	2.58	2.58	3.79	3.86	3.65	3.66	4.55	4.59
	% Predicted to Observed	94.9	94.9	99.6	101.4	100.2	100.4	98.5	99.5
Dryland Agriculture Consumption	Kg	857.0	857.0	1055.8	1067.7	1317.7	1319.7	2297.4	2313.0
	% Predicted to Observed	82.2	82.2	79.3	80.2	87.6	87.7	88.0	88.6
Dryland Agriculture Sales	Kg	182.1	182.1	413.8	427.7	374.5	376.7	773.5	787.2
	% Predicted to Observed	329.9	329.8	270.4	279.5	163.9	164.9	136.7	139.1
Gardens Acreage	Acres	0.49	0.49	0.34	0.31	0.43	0.43	0.46	0.44
	% Predicted to Endowment	125.7	125.7	101.9	93.5	99.2	98.2	106.8	102.5
Gardens Consumption	Kg	153.8	153.8	101.6	93.3	154.5	153.0	307.9	295.4
	% Predicted to Observed	125.7	125.7	102.0	101.6	98.8	97.8	106.7	102.4
Gardens Sales	Kg	150.8	150.8	120.3	110.4	176.2	172.5	273.0	262.0
	% Predicted to Observed	125.8	125.8	101.9	93.5	99.7	98.6	106.8	102.5

Notes:
a. DEVROOT = square root of the sum of squared deviations between the observed and predicted values of output.

Table 7.3 Coefficients of Absolute and Relative Risk Aversion for Tri-sector Models

	Single Risk Parameter		Triple Risk Parameters					
	Gardens, Dryland Agriculture, and Woodlands Sectors Combined		Gardens		Dryland Agriculture		Woodlands	
	COARA[a]	CORRA[b]	COARA	CORRA	COARA	CORRA	COARA	CORRA
Lowest 25%	$7.52X10^{-5}$	2.38	$7.01X10^{-5}$ >	2.22 >	$3.97X10^{-5}$	1.26	0.000118 >>	3.75 >>
25-50%	0.000102	3.92	$8.57X10^{-5}$ >	3.29 >	0.000155 >>	5.95 >>	$5X10^{-5}$	1.92
50-75%	0.000151	8.16	0.000141	7.59	0.00015 >	8.08 >	0.000164 >>	8.85 >>
Top 25%	$8.370X10^{-5}$ -$8.374X10^{-5}$	7.24-7.25	$8.26X10^{-5}$ =	7.15 =	$8.26X10^{-5}$ =	7.15 =	$8.66X10^{-5}$ >	7.49 >

Notes:

a. COARA = Coefficient of Absolute Risk Aversion.
b. CORRA = Coefficient of Relative Risk Aversion.
\> second most risk averse sector
\>> most risk averse
= Equal risk aversion

Table 7.4 Results for Best Performing Tri-Sector Models

Predicted Variable	Unit/ Predicted Percentage	Single (Lowest 25%)	Triple (Lowest 25%)	Single (25-50%)	Triple (25-50%)	Single (50-75%)	Triple (50-75%)	Single (Top 25%)	Triple (Top 25%)
DEVROOT[a]	Z$	462.9	550.9	598.9	630.5	606.6	609.6	1799.0	1799.4
	% DEVROOT to Observed Output Value	4.8	5.7	5.3	5.6	4.6	4.6	8.1	8.1
Dryland Agriculture Acreage	Acres	2.62	2.53	3.70	3.64	3.54	3.52	4.45	4.44
	% Predicted to Observed	96.5	93.3	97.2	95.5	97.2	96.7	96.5	96.3
Dryland Agriculture Consumption	Kg	873.7	843.9	1082.5	1061.1	1298.7	1291.1	2322.0	2316.3
	% Predicted to Observed	83.8	80.9	81.3	79.7	86.3	85.8	89.0	88.7
Dryland Agriculture Sales	Kg	182.5	177.5	351.7	347.6	342.6	341.9	686.3	685.8
	% Predicted to Observed	330.8	321.6	229.8	227.2	149.9	149.6	121.3	121.2
Gardens Acreage	Acres	0.49	0.49	0.46	0.46	0.53	0.53	0.62	0.62
	% Predicted to Observed	125.7	125.7	138.7	138.7	123.0	123.0	142.8	142.8
Gardens Consumption	Kg	153.8	153.8	138.3	138.3	191.6	191.6	411.8	411.8
	% Predicted to Observed	125.7	125.7	138.9	138.9	122.5	122.5	142.7	142.7
Gardens Sales	Kg	150.8	150.8	163.7	163.7	216.0	216.0	365.2	365.2
	% Predicted to Observed	125.8	125.8	138.6	138.6	123.5	123.5	142.9	142.9
Woodlands Time	Hours	939.1	1042.5	742.4	810.5	808.0	827.0	458.8	468.9
	% Predicted to Observed	94.9	105.3	78.1	85.3	87.9	90.0	61.3	62.6
Woodlands Consumption	Kg	6624.6	7503.4	5646.3	6225.3	6063.1	6224.0	3482.1	3568.2
	% Predicted to Observed	90.5	102.5	86.2	95.0	83.5	85.8	47.5	48.6
Woodlands Sales	Kg	1358.1	1358.1	663.8	663.8	805.2	805.2	417.5	417.5
	% Predicted to Observed	100	100	100	100	100	100	100	100

Notes:

a. DEVROOT = square root of the sum of squared deviations between the observed and predicted values of output.

Table 7.5 Results for Best Performing Double Sector and Tri-Sector Models (Single Risk Parameter)

Predicted Variable	Unit/ Predicted Percentage	Number of Sectors							
		Double	Triple	Double	Triple	Double	Triple	Double	Triple
		Wealth Quartile							
		Lowest 25%		25-50%		50-75%		Top 25%	
DEVROOT[a]	Z$	482.3	462.9	41.4	598.9	22.6	606.6	334.8	1799.0
	% DEVROOT to Observed Output Value	6.5	4.8	0.4	5.3	0.2	4.6	1.6	8.1
Dryland Agriculture Acreage	Acres	2.58	2.62	3.79	3.70	3.65	3.54	4.55	4.45
	% Predicted to Observed	94.9	96.5	99.6	97.2	100.2	97.2	98.5	96.5
Dryland Agriculture Consumption	Kg	857.0	873.7	1055.8	1082.5	1317.7	1298.7	2297.4	2322.0
	% Predicted to Observed	82.2	83.8	79.3	81.3	87.6	86.3	88.0	89.0
Dryland Agriculture Sales	Kg	182.1	182.5	413.8	351.7	374.5	342.6	773.5	686.3
	% Predicted to Observed	329.9	330.8	270.4	229.8	163.9	149.9	136.7	121.3
Gardens Acreage	Acres	0.49	0.49	0.34	0.46	0.43	0.53	0.46	0.62
	% Predicted to Observed	125.7	125.7	101.9	138.7	99.2	123.0	106.8	142.8
Gardens Consumption	Kg	153.8	153.8	101.6	138.3	154.5	191.6	307.9	411.8
	% Predicted to Observed	125.7	125.7	102.0	138.9	98.8	122.5	106.7	142.7
Gardens Sales	Kg	150.8	150.8	120.3	163.7	176.2	216.0	273.0	365.2
	% Predicted to Observed	125.8	125.8	101.9	138.6	99.7	123.5	106.8	142.9
Woodlands Time	Hours		939.1		742.4		808.0		458.8
	% Predicted to Observed		94.9		78.1		87.9		61.3
Woodlands Consumption	Kg		6624.6		5646.3		6063.1		3482.1
	% Predicted to Observed		90.5		86.2		83.5		47.5
Woodlands Sales	Kg		1358.1		663.8		805.2		417.5
	% Predicted to Observed		100		100		100		100

Notes:

a. DEVROOT = square root of the sum of squared deviations between the observed and predicted values of output.

CHAPTER 8

Policy Simulations

8.1 Introduction

This section presents results of applying the household model in a policy analysis. One of the study objectives outlined in Sections 1.2 and 2.4.1 was to assess the possible impact of interventions or development projects on livelihoods of smallholder agricultural producers. Given that financial capital has been cited as a major constraint in smallholder systems in semi-arid areas (Mortimore 1998), the specific policy situation examined in this study relates to household participation in a micro-credit scheme. This analysis was done to demonstrate the potential use of policy simulations within a household model framework to policy makers and other development related agencies.

Background information on the Simudzirayi Micro-credit Scheme that was implemented in the survey area is presented first. This is followed by a presentation of results for policy simulations based on different levels of a cash loan.

8.2 Background on the Simudzirayi Micro-credit Scheme

The Simudzirayi micro-credit scheme was established in 1998 through funds from War on Want (WW), the initial donation being Z$44 000 (Mutamba *et al* 2000). The scheme was implemented in three villages in Romwe comprising of 136 households. The objectives of the scheme were to better the lives of farmers who live within the Romwe Community (Tamwa, Dhobani and Sihambe villages) by assisting them with the procurement of farming inputs, livestock or funding any project that may generate cash for the farmers (Mutamba *et al* 2000). The program was thus geared towards alleviating financial constraints of the households. The funds went to people in the catchment, of different ages and gender, who were interested in undertaking projects of their own choice (Mutamba *et al* 2000). Loans were relatively equally distributed among wealth groups (Campbell *et al*, 2002). The Institute of Environmental Studies (IES) at the University of Zimbabwe allocated an additional Z$60 000 to the scheme in 1999. A selected committee ran the scheme. An interest rate of 40% was charged on loans. The committee determined the maximum amounts of money that could be given to individuals and also made decisions as to who could get the money. The progress of the scheme was closely monitored by the IES.

The initial plan was to give one loan per household. The value of the loans was to be either Z$500 or Z$1000. However some households received more than one loan with some receiving as much as Z$3000 in total loans. In 1999, people in positions of authority were allocated as much as Z$1500 or Z$3000. Thirty-seven percent of households in the three villages received loans in 1998, and 47% in 1999 (Campbell *et al*, 2002). The total value of the loans given out in 1998 and 1999 amounted to Z$45 000 and Z$55 000 respectively. Some of the projects that were initiated on the basis of these loans included: (a) poultry-keeping; (b) renting fields in order to grow cotton; (c) buying inputs (approximately 35% of the loans were used for this purpose) and, (d) trading in clothes (Mutamba *et al* 2000). Given the restrictions on the maximum amount of allowable loans it was sometimes difficult for an individual to carry out the proposed project (Mutamba *et al* 2000). In 1999, most farmers were said to have used the funds for inputs into dryland cropping (seed and fertiliser). With respect to household expectations on the longevity of the project, it is conjectured that households viewed the project as a temporary development intervention. This might have influenced household investment patterns; that is, they might have invested in projects that gave a quick return such as buying clothes for resale at the expense of more costly long-term projects such as cattle feeding.

8.3 Policy Simulations Based on Effect of Different Levels of a Cash Loan on Household Resource Allocation

This section presents results of policy simulations that were done to illustrate the potential use of the representative household model for policy analysis. The policy situation studied was the possible impact of different levels of a cash loan on household production, consumption and sales activities. It was assumed that the cash loan constituted a cash injection into the cash income equation (equation 3.5-6) and was available for use in gardens, dryland agriculture and woodlands sector activities. The policy situations examined were for cash loans that did not have any prerequisites attached in terms of requiring households to submit project proposals before accessing the loans. The simulations were therefore aimed at predicting the usage of loaned funds. A parameter representing the value of the loan was added to the right hand side of the cash income constraint (equation 3.12).

Tri-sector models were used for this analysis because they more closely approximated reality in the sense that they allowed for more sectors to be modelled endogenously compared to double sector models. The simulations were done by wealth quartile using best fitting tri-sector models with a single risk parameter. Tri-sector models with single risk parameters were selected for this analysis because there was little difference in results between single and multiple risk parameter tri-sector models for a given wealth group.

Three alternative values of cash injections (i.e., loans) were used in the model simulations; Z$500, Z$1000 and Z$2000. Most of the cash loans given out under the local Simudzirayi Micro-Credit Scheme were Z$500 and Z$1000, as specified in the program. The scenario with Z$2000 was included to reflect the reality of the program; that is, many households received more than the supposed upper limit of Z$1000. The base model case (no loan scenario) was used as a control while Z$2000 represented an upper bound for the loan. Results of loan simulations for varying activities are presented below. The interest cost for the credit was not considered given that the models for this simulation were estimated at a given point in time.

8.4 Results of Policy Simulation Models

Table 8.1 presents results for credit simulation models. There were no changes in garden activities (production, consumption or sales) over the range of loan values used in this analysis. The only dryland agriculture activities across wealth quartiles that changed were consumption and sales. Changes in woodlands activities were evident in wealth quartile 4.

Dryland agriculture acreage for wealth quartiles 1 and 2 did not change for any of the loan scenarios (i.e., from Z$0 to Z$2000). Dryland agriculture acreage for wealth quartile 3 showed a marginal increase of 1.1% when the value of the loan was at its maximum of Z$2000. Dryland agriculture acreage for wealth quartile 4 increased by 7.4% when the value of the loan was at Z$2000[53]. Results suggested that the introduction of a cash loan caused an increase in household consumption of dryland agriculture and a decrease in dryland agriculture sales (Table 8.1). The increase in dryland agriculture consumption at the expense of sales can be attributed to the fact that the loan constituted an increase in income for the household and so the household did not need to sell as much crops to support domestic expenditures.

Woodlands time did not change significantly at loan values of up to Z$2000 for wealth quartiles 1-3. These results suggested that the poorer households were more constrained resource-wise and therefore less likely to move out of woodlands activities. In the case of wealth quartile 4, time allocated to woodlands production decreased when the value of the loan was set at Z$1000 and Z$2000 (Table 8.1). The results for woodlands activities were consistent with observed data that showed that the wealthiest households spent the

53 Sensitivity analysis was done using loans of Z$3000, Z$4000, Z$5000 and $Z6000 to determine how high the loan value would have to be in order to have a significant change in dryland agriculture acreage. In the case of wealth quartiles 1 and 3, dryland agriculture acreage stabilized at 3.25 acres and 4.20 acres at loans of Z$5000 and Z$4000, respectively. Dryland agriculture acreages for wealth quartiles 2 and 4 at a loan of Z$6000 were 4.98 acres and 5.17acres, respectively.

least time in woodlands activities (Table 6.2). Moreover, results suggested that when the wealthiest households received sufficiently high loans, they substituted labour away from woodlands towards dryland agriculture. These shifts in inputs are also reflected in decreased woodland and increased dryland consumption.

Indications from the Simudzirayi Micro-credit Scheme Report were that the largest single use of the loans was buying dryland agriculture inputs. This model also showed that most of the loan money went into dryland agriculture. However, given the many factors that constrain what households may do in the models, it may be difficult to show marked changes in resource use even with the loan. Relaxing the constraints would be one way of dealing with this issue.

8.5 Summary of Policy Simulation Results

The results of this analysis suggested that an intervention in the form of a cash loan with no strings attached would allow smallholder producers to consume more and sell less dryland agriculture production. Results also showed a slight increase in dryland acreage for some wealth groups at higher values of the loan. The increase in agricultural production activities is consistent with findings from the Romwe micro-credit scheme that indicated most farmers used the funds for inputs into dryland cropping. Simulation results suggested that the wealthiest households decreased time allocated to woodlands production with an increase in the value of the loan.

Results also suggested that the range of loans used in the credit scheme was too low to have much of an influence on livelihood behaviour. The level of the loans was only sufficient to marginally change the behaviour of the richest households. Results therefore suggested that larger loans would be needed to significantly impact household behaviour.

This analysis has explored the potential use of household models as a policy tool to investigate development initiatives. However, the ability to look at this type of policy with this type of model is limited. The model developed in this study was incomplete given that some household activities were not modelled. For example, this analysis only looked at the role of credit in the activities of the three sectors (i.e., dryland agriculture, gardens and woodlands) modelled. The use of household loans for other household activities such as purchasing clothes for resale, paying dowry or funding poultry projects was not covered in this analysis. Specifically, the "household" and "livestock" sectors were not modelled explicitly in this study (Section 4.4). Another limitation of the model developed in this study was that extra cash derived from the loan was not tied to any specific projects. In reality, loans are tied to specific projects thus restricting the use to which they can be put. More insight can be gained into the usefulness of this type of model by incorporating more activities and restricting the use of loaned funds to specific projects. Another area for further study pertains to whether livelihoods of households may decline in situations where loans are tied to specific projects rather than allowing households to decide where best to put the borrowed money. Lastly, the possible impact of household expectations regarding longevity of development initiatives warrants further investigation as this may offer an explanation of household investment patterns under different scenarios.

Table 8.1 **Credit Simulation Results for Tri-Sector Models with a Single Risk Parameter**

Wealth Quartile	Variable	Unit/ % Predicted to Observed	Value of the Loan (Z$)			
			0	500	1000	2000
Lowest 25%	Dryland Agriculture Acreage	Acres	2.62	2.62	2.62	2.62
		%	96.5	96.5	96.5	96.5
	Dryland Agriculture Consumption	Kg	873.7	965.5	1055.9	1238.7
		%	83.8	92.6	101.3	118.8
	Dryland Agriculture Sales	Kg	182.5	91.8	0.8	0
		%	330.8	166.3	1.4	0
	Woodlands Time	Hours	939.1	935.8	937.7	934.1
		%	94.9	94.5	94.7	94.3
25-50%	Dryland Agriculture Acreage	Acres	3.70	3.70	3.70	3.70
		%	97.2	97.2	97.2	97.2
	Dryland Agriculture Consumption	Kg	1082.5	1172.0	1264.6	1445.5
		%	81.3	88.0	95.0	108.6
	Dryland Agriculture Sales	Kg	351.7	260.5	169.9	0
		%	229.8	170.2	111.0	0
	Woodlands Time	Hours	742.4	747.0	741.4	744.4
		%	78.1	78.6	78.0	78.3
50-75%	Dryland Agriculture Acreage	Acres	3.54	3.54	3.54	3.58
		%	97.2	97.2	97.2	98.4
	Dryland Agriculture Consumption	Kg	1298.7	1389.5	1480.2	1681.8
		%	86.3	92.4	98.4	111.8
	Dryland Agriculture Sales	Kg	342.6	251.7	160.8	0
		%	149.9	110.1	70.4	0
	Woodlands Time	Hours	808.0	808.3	808.8	759.4
		%	87.9	87.9	87.9	82.6
Top 25%	Dryland Agriculture Acreage	Acres	4.45	4.45	4.54	4.78
		%	96.5	96.5	98.4	103.6
	Dryland Agriculture Consumption	Kg	2322.0	2413.0	2556.2	2885.6
		%	89.0	92.4	97.9	110.5
	Dryland Agriculture Sales	Kg	686.3	595.4	509.8	343.0
		%	121.3	105.2	90.1	60.6
	Woodlands Time	Hours	458.8	458.7	366.2	105.5
		%	61.3	61.3	48.9	14.1

CHAPTER 9

Conclusions

9.1 Introduction

This chapter presents a summary of the thesis, conclusions of the study, as well as limitations and areas for further research. The chapter starts by presenting a summary of the problem, objectives of the study, methods used and a summary of the results. This is followed by a description of the conclusions of the study. Limitations of the study are then presented. Lastly, areas for further research are proposed.

9.2 Problem Statement and Objectives

Previous studies have highlighted the importance of risk on household decision-making. Despite this importance, few studies have integrated risk in modelling the behaviour of smallholder agricultural producers in developing countries. The objective of this study is to present models of the microeconomic behaviour of smallholder agricultural producers within a risk programming framework. It is hoped that the results of this study will provide an improved understanding of household behaviour under risk.

The general goal of this study was to simulate the behaviour of smallholder agricultural producers using a risk programming approach. The objectives of this study were to:

(a) examine whether leisure has to be modelled explicitly in household models,

(b) estimate risk preferences for a sample of smallholder agricultural households,

(c) investigate whether results of partial sector models are improved by increasing the number of sectors being modelled,

(d) investigate whether results of household models are improved by increasing the number of risk parameters being modelled and,

(e) to assess the potential for using the household models in policy analysis.

This study was based on household-farm level data collected for Zimbabwean smallholder agricultural producers in Chivi District of Masvingo Province. The survey was conducted as a quarterly household income and expenditure survey, over 15 months from late 1998 to early 2000. The analysis was based on a final sample of 199 households of which 124 were in Romwe and 75 were in Mutangi. A risk programming approach was used to model the micro-economic behaviour of smallholder agricultural producers. The Utility Efficient (UE) programming model was selected as the behavioural model in this study.

9.3 Summary of the Results and Conclusions

This section presents a summary of the main findings of this study and the conclusions.

9.3.1 Modeling Leisure in Household Models of Smallholder Producers

Two alternative approaches have been proposed pertaining to the treatment of leisure in household models. One school of thought was based on the premise that the opportunity cost of leisure varies seasonally and leisure should therefore be explicitly modelled in order to capture the opportunity cost of alternative time use. Under these conditions new activities or projects that require labour during periods of high demand will be less likely to succeed, while projects introduced during seasons of low labour demand will have a higher probability of success. This logic assumes that the demand for labour displays significant seasonal fluctuations. A second school of thought was based on the premise that it may be difficult to distinguish between work and leisure since households use the "leisure" time for household maintenance activities.

The degree of seasonal variation in labour demand was investigated using three approaches: (a) analysis of sleep/relaxation time, (b) analysis of wages, and (c) analysis of substitutability of activities. Results of the three investigations into the seasonality in the opportunity costs of labour showed that leisure, defined as sleeping plus relaxing time, appeared to be relatively constant despite evidence of seasonality in the opportunity cost of labour in one quarter. This evidence did not constitute a strong relationship. Lack of consistency in the results of the three investigations into the seasonality of in the opportunity cost of labour suggested that there was no justification for including leisure as an explicit activity in the risk programming models of smallholder agricultural producers. It was therefore assumed that leisure was relatively constant.

9.3.2 Estimation of Risk Preferences

In all cases where there were determinate results regarding risk preferences (i.e. all models except for wealth quartile 1 with two sectors), wealth groups generally displayed high levels of risk aversion when compared to ranges suggested in the literature. Given that the literature was largely based on research from developed country studies, the high values obtained in this study are deemed to be plausible in the context of the low incomes in the study area.

In general the models did a good job in replicating observed behaviour, which gave some confidence in the derived risk preferences derived. However, some evidence in the results was seen that suggested that the constrained nature of the decisions undertaken by these households may prevent their risk preferences from being expressed in their behaviour.

9.3.3 Comparison of Results of Models with Alternative Sectors

Whether results of partial sector models are improved by increasing the number of sectors being modelled was investigated by comparing results for double sector and tri-sector models. The comparison produced inconclusive results. For wealth quartile 1, tri-sector models (which include woodlands) performed better than two sector models, likely because of the important role played by woodlands in poor households. For wealth quartiles 2 through 4, where woodlands play a smaller role, the benefits of adding an additional sector seem to be outweighed by the problems associated with the complexity in modelling the additional woodlands sector.

9.3.4 Comparison of Results of Models with Alternative Risk Preference Parameters

The investigation of whether results of household models are improved by increasing the number of risk parameters modelled was undertaken by comparing results of single and sector specific risk parameter models. There was little difference in results between single and multiple risk parameter models for a given wealth group. The results therefore suggested that there was no advantage in pursuing multiple risk parameter models. That is, household behaviour could be effectively modelled using a univariate utility function. This result could, however, be a reflection of the modelling environment used in this study, which could prevent higher degrees of modelling resolution from showing positive results.

9.3.5 Policy Simulations Based on Credit Availability

The models were generally successful in predicting the response of households to increased credit availability. The models predicted that an increase in cash would be directed towards increasing dryland agricultural activities, which is largely what happened on the ground. Moreover, model results suggested that loan amounts were likely too small to make much of a difference in household behaviour. This problem was also realized by the administrators of the credit scheme who attempted to increase the values of loans as the project proceeded.

9.4 Limitations of the Study and Implications for Further Research

While extensive household data were available for use in this study, there were still data problems. Specifically, there was a lack of available household level data for time series yields and prices. It was therefore necessary to extrapolate data from far afield for local use.

A further limitation of the study pertains to difficulties in modelling the woodlands sector. The complexity and range of the products produced and consumed in this sector created challenges in modelling. Although some of those difficulties may be addressed through finer resolution by sub-dividing the sector, complications associated with increasing models to accommodate too many sectors may prove challenging. Nonetheless, the failure of the models in this thesis to account for some important livelihood sectors, such as livestock, suggest an important area for further research.

Another limitation pertaining to this study concerns the static nature of the models given that household decisions have dynamic implications. For example, if livestock considerations were to be added to this model, production decisions in one year would be heavily influenced by expectations beyond the current year. The current structure of the model does not allow for these types of considerations to be incorporated into the analysis. Thus further insight into the research issues identified in this study may be gained by incorporating dynamics into the models.

Another area for further research pertains to the potentially stochastic nature of labour availability. For example, the impact of the AIDS pandemic on household labour resources and production decisions present a major source of uncertainty regarding labour allocation and production decisions. Responses to this risk may be investigated using simulated changes in the labour resources.

The models in this thesis also assume that households maximize expected utility. A number of experimental procedures could be undertaken to test whether their behaviour is consistent with this theory, or whether some other behavioural theory would be more applicable.

Lastly, further research is needed on the study of households' objective and subjective perceptions of risk. In this study, it is assumed that perceptions of risk are shaped by historic events where each year contributes equally in the formation of risk perceptions. Further empirical research could test this assumption.

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APPENDICES

APPENDIX A

Syntax for GAMS Models

This appendix provides the structures of GAMS (Generalized Algebraic Modelling Systems) models used in this study. The structure of double sector household models is presented first followed by that for three sector models.

A1 Double Sector Model With One Risk Parameter for Wealth Quartile 1

```
$offlisting
$offsymxref
$offsymlist

SETS
J  sub-sector /wet,dry/
K  states of nature /1,2,3,4,5,6,7,8,9,10/;

PARAMETERS

LABOUR(J)  labour requirement per acre of cropped sub-sector J (hours per acre)
/ wet   1643.3
  dry   1196.5 /

DRAFT(J)  draft requirement in hours per acre of sub-sector J
/ wet   0
  dry   3 /

VC(J)  variable cost per acre (planted) for sub-sector J in Z$ excluding labour
/ wet   104.77
  dry   172.58 /

TABLE CONPRI(J,K)  consumption value of subsector J in state of nature K
        1      2      3      4      5      6      7      8      9      10
wet     2.58   2.63   2.07   2.36   1.60   2.40   2.85   2.28   2.50   3.00
dry     5.17   5.22   4.78   5.01   4.42   5.04   5.38   4.94   5.12   5.50;

TABLE BUYPRI(J,K)  purchase value of subsector J in state of nature K
        1      2      3      4      5      6      7      8      9      10
wet     5.16   5.27   4.14   4.72   3.20   4.80   5.70   4.55   5.01   6.00
dry     5.17   5.22   4.78   5.01   4.42   5.04   5.38   4.94   5.12   5.50;

TABLE SELLPRI(J,K)  sales value of subsector J in state of nature K
        1      2      3      4      5      6      7      8      9      10
wet     5.16   5.27   4.14   4.72   3.20   4.80   5.70   4.55   5.01   6.00
dry     5.17   5.22   4.78   5.01   4.42   5.04   5.38   4.94   5.12   5.50;
```

TABLE YLDKG(J,K) yield in kg per acre of subsector J in state of nature K

	1	2	3	4	5	6	7	8	9	10
wet	602.02	602.5	603.29	608.65	611.91	613.46	629.56	654.87	617.22	623.24
dry	151.84	588.38	150.65	520.58	174.95	293.87	496.75	240.74	200.74	403.21;

SCALARS

WAGEH	wage rate for hired labour in Z$ per hour / 9 /
LAMBDA1	risk aversion parameter / 0 /
A1	value of COARA when LAMBDA1=0 /0.0000035051 /
B1	value of COARA when LAMBDA1 approaches infinity / 0.000421 /
PROBK	probability of state of nature K / 0.1 /
DRYEND	dryland land endowment in acres / 4.8510 /
WETEND	garden land endowment in acres / 0.4888 /
DRAFTAVAIL	household draft supply in hours / 1.4 /
PDL	cost of hiring one hour of draft (Z$ per hr) / 50 /
LABSUP	household labour supply in labour equiv hours / 3886.5486 /
WETPCT	percentage of wetland sales to production / 0.495 /
WETOBS	garden value of production observed in Z$ / 1453.80 /
DRYOBS	dryland value of production observed in Z$ / 6019.31 /
DOMEXP1	state of nature 1 subsidy to domestic sector / 508.77 /
DOMEXP2	state of nature 2 subsidy to domestic sector / 1377.64 /
DOMEXP3	state of nature 3 subsidy to domestic sector / 442.71 /
DOMEXP4	state of nature 4 subsidy to domestic sector / 1181.53 /
DOMEXP5	state of nature 5 subsidy to domestic sector / 426.05 /
DOMEXP6	state of nature 6 subsidy to domestic sector / 210.93 /
DOMEXP7	state of nature 7 subsidy to domestic sector / 1256.20 /
DOMEXP8	state of nature 8 subsidy to domestic sector / 653.19 /
DOMEXP9	state of nature 9 subsidy to domestic sector / 599.09 /
DOMEXP10	state of nature 10 subsidy to domestic sector / 1093.83 /
RA	"coefficient of absolute risk aversion"
RR	"coefficient of relative risk aversion"
DEVSQ	"sum of squared deviations between predicted and observed value of production" ;

VARIABLES

Z1	objective function representing E(U) (model 1)
PRDN(J)	area under sub-sector J in acres
CON(J,K)	amount of sub-sector J consumed in kg in state of nature K
SELL(J,K)	sales of sub-sector J in state of nature K
BUY(J,K)	purchases of sub-sector J in state of nature K
HL	hours of hired labour
DL	hours of hired draft
GVALUE	garden value of production
DVALUE	dryland value of production
WETPRKG	predicted garden output in kgs
DRYPRKG	predicted dryland output in kgs
Y(K)	household cash income in state of nature K ;

```
POSITIVE VARIABLES PRDN, CON, SELL, BUY, HL, DL, GVALUE, DVALUE, Y;

EQUATIONS

OBJECTIVE1   expected utility function (model 1)
LANDDRY      dryland area ownership constraint
LANDWET      wetland area ownership constraint
LAB          production labour constraint
DPOWER       draught power constraint
KON(J,K)     consumption constraint
INCOME1      state of nature 1 cash income constraint
INCOME2      state of nature 2 cash income constraint
INCOME3      state of nature 3 cash income constraint
INCOME4      state of nature 4 cash income constraint
INCOME5      state of nature 5 cash income constraint
INCOME6      state of nature 6 cash income constraint
INCOME7      state of nature 7 cash income constraint
INCOME8      state of nature 8 cash income constraint
INCOME9      state of nature 9 cash income constraint
INCOME10     state of nature 10 cash income constraint
WETKG        garden output constraint
DRYKG        dryland output constraint
WETSELL(K)   allowable garden sales constraint
GPRODVAL     garden constraint on predicted value of production
DPRODVAL     dryland constraint on predicted value of production;

OBJECTIVE1 .. Z1 =E= sum(K, PROBK*(-EXP(-A1*SUM(J,CONPRI(J,K)*CON(J,K))) -
LAMBDA1*EXP(-B1*SUM(J,CONPRI(J,K)*CON(J,K))))) ;
LANDDRY .. PRDN('dry') =L= DRYEND ;
LANDWET .. PRDN('wet') =L= WETEND ;
WETKG .. WETPRKG =E= YLDKG("WET","10")*PRDN("WET") ;
DRYKG .. DRYPRKG =E= YLDKG("DRY","10")*PRDN("DRY") ;
LAB .. sum(J, LABOUR(J)*PRDN(J)) - HL =L= LABSUP ;
DPOWER .. sum(J, DRAFT(J)*PRDN(J)) =L= DRAFTAVAIL + DL ;
KON(J,K) .. CON(J,K) =E= YLDKG(J,K)*PRDN(J) + BUY(J,K) - SELL(J,K) ;
WETSELL(K)..SELL("WET",K) =L= WETPCT*YLDKG("WET",K)*PRDN("WET") ;
INCOME1 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"1"))+DOMEXP1 =L= sum(J, SELLPRI(J,"10")*SELL(J,"1"));
INCOME2 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"2"))+DOMEXP2 =L= sum(J, SELLPRI(J,"10")*SELL(J,"2"));
INCOME3 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"3"))+DOMEXP3 =L= sum(J, SELLPRI(J,"10")*SELL(J,"3"));
INCOME4 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"4"))+DOMEXP4 =L= sum(J, SELLPRI(J,"10")*SELL(J,"4"));
INCOME5 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"5"))+DOMEXP5 =L= sum(J, SELLPRI(J,"10")*SELL(J,"5"));
INCOME6 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"6"))+DOMEXP6 =L= sum(J, SELLPRI(J,"10")*SELL(J,"6"));
INCOME7 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"7"))+DOMEXP7 =L= sum(J, SELLPRI(J,"10")*SELL(J,"7"));
INCOME8 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"8"))+DOMEXP8 =L= sum(J, SELLPRI(J,"10")*SELL(J,"8"));
INCOME9 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"9"))+DOMEXP9 =L= sum(J, SELLPRI(J,"10")*SELL(J,"9"));
```

```
INCOME10 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"10"))+DOMEXP10 =L= sum(J, SELLPRI(J,"10")*SELL(J,"10"));
GPRODVAL .. GVALUE =E= SELLPRI("wet","10")*YLDKG("wet","10")*PRDN("wet") ;
DPRODVAL .. DVALUE =E= SELLPRI("dry","10")*YLDKG("dry","10")*PRDN("dry") ;

MODEL UTILITY1 / ALL / ;

option limcol = 0;

set iter / i1*i1000 /;
Parameter Rep(Iter,*);

option decimals = 8;

loop(iter,
LAMBDA1 = LAMBDA1 + 0.0001 ;

option nlp=minos5 ;
SOLVE UTILITY1 USING NLP MAXIMIZING Z1 ;
RA = (SQR(A1)*EXP(-A1*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*SQR(B1)*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A1*EXP(-
A1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*B1*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
DEVSQ = SQR(GVALUE.L-WETOBS)+SQR(DVALUE.L-DRYOBS);
RR = RA*31699.8543;
Rep(Iter,'Devsq') = devsq;
Rep(Iter,'Lambda1') = lambda1;
Rep(Iter,'COARA') = ra;
Rep(Iter,'CORRA') = rr;
Rep(Iter,'wetacre') = prdn.l("wet");
Rep(Iter,'dryacre') = prdn.l("dry");
Rep(Iter,'wetkg') = wetprkg.l;
Rep(Iter,'drykg') = dryprkg.l;
Rep(Iter,'agrhr') = lab.l;
Rep(Iter,'hirelab') = hl.l;
Rep(Iter,'hiredr') = dl.l;
Rep(Iter,'wetcon10') = con.l("wet","10");
Rep(Iter,'drycon10') = con.l("dry","10");
Rep(Iter,'wetsell10') = sell.l("wet","10");
Rep(Iter,'drysell10') = sell.l("dry","10");
Rep(Iter,'wetbuy10') = buy.l("wet","10");
Rep(Iter,'drybuy10') = buy.l("dry","10");
Rep(Iter,'utils') = Z1.l);

$libinclude xldump rep rep1sn99y.gc50.9.50.xls
display rep;
```

A2 Double Sector Model With Two Risk Parameters for Wealth Quartile 1

This section provides a listing of the changes that are needed in the programming in order for the double sector model with a single risk parameter to accommodate a second risk parameter.

```
SCALARS

LAMBDA1     gardens risk aversion parameter  / 0 /
LAMBDA2     dryland risk aversion parameter  / 0 /
A1          value of COARA1 when LAMBDA1=0  / 0.0000035051 /
B1          value of COARA1 when LAMBDA1 approaches infinity / 0.000421 /
A2          value of COARA2 when LAMBDA2=0  / 0.0000035051 /
B2          value of COARA2 when LAMBDA2 approaches infinity / 0.000421 /
RA1         "gardens coefficient of absolute risk aversion"
RA2         "dryland coefficient of absolute risk aversion"
RR1         "gardens coefficient of relative risk aversion"
RR2         "dryland coefficient of relative risk aversion"

OBJECTIVE1 .. Z1 =E= sum(K, PROBK*(-EXP(-A1*SUM(J,CONPRI(J,K)*CON(J,K))) -
LAMBDA1*EXP(-B1*SUM(J,CONPRI(J,K)*CON(J,K))))) + sum(K, PROBK*(-EXP(-
A2*SUM(J,CONPRI(J,K)*CON(J,K))) - LAMBDA2*EXP(-B2*SUM(J,CONPRI(J,K)*CON(J,K)))));

MODEL UTILITY1 / ALL / ;

option limcol = 0;
option decimals =  8 ;

set iter1 / i1*i32 /;
ALIAS (ITER1, ITER2);

Parameter Rep(Iter1,Iter2,*);

* loop for each lambda1
loop(iter1,
LAMBDA1 = LAMBDA1 + 0.003125;
lambda2 = 0;
* loop for each lambda2 for each lambda1
loop(iter2,
LAMBDA2 = LAMBDA2 + 0.003125;

display '+++++ ', lambda1, ' ', lambda2;

option nlp=minos5;
SOLVE UTILITY1 USING NLP MAXIMIZING Z1;
RA1 = (SQR(A1)*EXP(-A1*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*SQR(B1)*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A1*EXP(-
```

```
A1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*B1*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RA2 = (SQR(A2)*EXP(-A2*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA2*SQR(B2)*EXP(-
B2*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A2*EXP(-
A2*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA2*B2*EXP(-
B2*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RR1 = RA1*31699.8543;
RR2 = RA2*31699.8543;
DEVSQ = SQR(GVALUE.L-WETOBS)+SQR(DVALUE.L-DRYOBS);
Rep(Iter1,Iter2,'Devsq') = devsq;
Rep(Iter1,Iter2,'Lambda1') = lambda1;
Rep(Iter1,Iter2,'Lambda2') = lambda2;
Rep(Iter1,Iter2,'COARA1') = ra1;
Rep(Iter1,Iter2,'COARA2') = ra2;
Rep(Iter1,Iter2,'CORRA1') = rr1;
Rep(Iter1,Iter2,'CORRA2') = rr2;
Rep(Iter1,Iter2,'wetacre') = prdn.l("wet");
Rep(Iter1,Iter2,'dryacre') = prdn.l("dry");
Rep(Iter1,Iter2,'wetkg') = wetprkg.l;
Rep(Iter1,Iter2,'drykg') = dryprkg.l;
Rep(Iter1,Iter2,'agrhr') = lab.l;
Rep(Iter1,Iter2,'hirelab') = hl.l;
Rep(Iter1,Iter2,'hiredr') = dl.l;
Rep(Iter1,Iter2,'wetcon10') = con.l("wet","10");
Rep(Iter1,Iter2,'drycon10') = con.l("dry","10");
Rep(Iter1,Iter2,'wetsell10') = sell.l("wet","10");
Rep(Iter1,Iter2,'drysell10') = sell.l("dry","10");
Rep(Iter1,Iter2,'wetbuy10') = buy.l("wet","10");
Rep(Iter1,Iter2,'drybuy10') = buy.l("dry","10");
Rep(Iter1,Iter2,'utils') = Z1.l);
 );

$libinclude xldump rep arep1sn99y.gc50.9.50.xls
display rep;
```

A3 Tri-Sector Model With One Risk Parameter for Wealth Quartile 1

```
offlisting
$offsymxref
$offsymlist

SETS
J  sector /wet,dry,wood/
K  states of nature /1,2,3,4,5,6,7,8,9,10/;

PARAMETERS

LABOUR(J)  labour requirement per unit of sector J (hours per unit)
/ wet   1643.3
  dry   1196.5
  wood  1 /

DRAFT(J)  draft requirement in hours per acre of sector J
/ wet   0
  dry   3
  wood  0 /

VC(J)  variable cost per unit for sector J in Z$ excluding labour
/ wet   104.77
  dry   172.58
  wood  0.0 /

TABLE CONPRI(J,K)  consumption value of subsector J in state of nature K
        1       2       3       4       5       6       7       8       9       10
wet     2.58    2.63    2.07    2.36    1.60    2.40    2.85    2.28    2.50    3.00
dry     5.17    5.22    4.78    5.01    4.42    5.04    5.38    4.94    5.12    5.50
wood    0.12    0.12    0.12    0.12    0.12    0.12    0.12    0.12    0.12    0.13;

TABLE BUYPRI(J,K)  purchase value of subsector J in state of nature K
        1       2       3       4       5       6       7       8       9       10
wet     5.16    5.27    4.14    4.72    3.20    4.80    5.70    4.55    5.01    6.00
dry     5.17    5.22    4.78    5.01    4.42    5.04    5.38    4.94    5.12    5.50
wood    0.25    0.25    0.25    0.25    0.24    0.25    0.25    0.25    0.25    0.25;

TABLE SELLPRI(J,K)  sales value of subsector J in state of nature K
        1       2       3       4       5       6       7       8       9       10
wet     5.16    5.27    4.14    4.72    3.20    4.80    5.70    4.55    5.01    6.00
dry     5.17    5.22    4.78    5.01    4.42    5.04    5.38    4.94    5.12    5.50
wood    0.25    0.25    0.25    0.25    0.24    0.25    0.25    0.25    0.25    0.25;

TABLE YLDKG(J,K)  yield in kg per acre of sub-sector J in state of nature K
        1       2       3       4       5       6       7       8       9       10
wet     602.02  602.5   603.29  608.65  611.91  613.46  629.56  654.87  617.22  623.24
dry     151.84  588.38  150.65  520.58  174.95  293.87  496.75  240.74  200.74  403.21
wood    7.80    9.02    7.80    8.83    7.86    8.20    8.76    8.05    7.94    8.50;
```

SCALARS

WAGEH	wage rate for hired labour in Z$ per hour / 9 /
LAMBDA1	risk aversion parameter / 0 /
A1	value of COARA when LAMBDA1=0 / 0.0000035051 /
B1	value of COARA when LAMBDA1 approaches infinity / 0.000421 /
PROBK	probability of state of nature K / 0.1 /
DRYEND	dryland land endowment in acres / 4.8510 /
WETEND	garden land endowment in acres / 0.4888 /
DRAFTAVAIL	household draft supply in hours / 1.4 /
PDL	cost of hiring one hour of draft ($ per hr) / 50 /
MLABSUP	household labour supply in labour equiv hours / 4876.60 /
WETOBS	garden value of production observed in Z$ / 1453.80 /
DRYOBS	dryland value of production observed in Z$ / 6019.31 /
WOODOBS	woodlands value of production observed in Z$ / 2169.38 /
WETPCT	percentage of wetland sales to production / 0.495 /
WOODSOLD	observed mean woodlands sales / 1358.07 /
MDOMEXP1	state of nature 1 subsidy to domestic sector / 795.72 /
MDOMEXP2	state of nature 2 subsidy to domestic sector / 1729.59 /
MDOMEXP3	state of nature 3 subsidy to domestic sector / 725.75 /
MDOMEXP4	state of nature 4 subsidy to domestic sector / 1520.57 /
MDOMEXP5	state of nature 5 subsidy to domestic sector / 709.07 /
MDOMEXP6	state of nature 6 subsidy to domestic sector / 475.84 /
MDOMEXP7	state of nature 7 subsidy to domestic sector / 1597.10 /
MDOMEXP8	state of nature 8 subsidy to domestic sector / 951.20 /
MDOMEXP9	state of nature 9 subsidy to domestic sector / 892.80 /
MDOMEXP10	state of nature 10 subsidy to domestic sector / 1422.11 /
RA1	"coefficient of absolute risk aversion"
RR1	"coefficient of relative risk aversion"
DEVSQ	"sum of squared deviations between predicted and observed value of production" ;

VARIABLES

Z1	objective function representing E(U) (model 1)
PRDN(J)	area (hours devoted to woodlands) under sector J in acres
CON(J,K)	amount of sector J consumed in kg in state of nature K
SELL(J,K)	sales of sector J in state of nature K
BUY(J,K)	purchases of sector J in state of nature K
HL	hours of hired labour
DL	hours of hired draft
GVALUE	garden value of production
DVALUE	dryland value of production
WVALUE	woodlands value of production
WETPRKG	predicted garden output in kgs
DRYPRKG	predicted dryland output in kgs
LABAGR	agric labour time (AE hrs)
LABWOOD	woodlands labour time (AE hrs)
Y(K)	household cash income in state of nature K ;

POSITIVE VARIABLES PRDN, CON, SELL, BUY, HL, DL, GVALUE, DVALUE, WVALUE, WETPRKG, DRYPRKG, LABAGR, LABWOOD, Y;

EQUATIONS

```
OBJECTIVE1    expected utility function (model 1)
LANDDRY       dryland area ownership constraint
LANDWET       wetland area ownership constraint
TOTLAB        total labour supply constraint
AGRLAB        agric labour supply constraint
WOODLAB       woodlands labour supply constraint
DPOWER        draught power constraint
KON(J,K)      consumption constraint
INCOME1       state of nature 1 cash income constraint
INCOME2       state of nature 2 cash income constraint
INCOME3       state of nature 3 cash income constraint
INCOME4       state of nature 4 cash income constraint
INCOME5       state of nature 5 cash income constraint
INCOME6       state of nature 6 cash income constraint
INCOME7       state of nature 7 cash income constraint
INCOME8       state of nature 8 cash income constraint
INCOME9       state of nature 9 cash income constraint
INCOME10      state of nature 10 cash income constraint
WETKG         garden output constraint
DRYKG         dryland output constraint
WETSELL(K)    allowable garden sales constraint
WOODSELL(K)   allowable woodland sales constraint
GPRODVAL      garden constraint on predicted value of production
DPRODVAL      dryland constraint on predicted value of production
WPRODVAL      woodlands constraint on predicted value of production ;

OBJECTIVE1 .. Z1 =E= 1000*(sum(K, PROBK*(-EXP(-A1*SUM(J,CONPRI(J,K)*CON(J,K))) -
LAMBDA1*EXP(-B1*SUM(J,CONPRI(J,K)*CON(J,K)))))) ;
LANDDRY .. PRDN('dry') =L= DRYEND ;
LANDWET .. PRDN('wet') =L= WETEND ;
WETKG .. WETPRKG =E= YLDKG("WET","10")*PRDN("WET") ;
DRYKG .. DRYPRKG =E= YLDKG("DRY","10")*PRDN("DRY") ;
WETSELL(K)..SELL("WET",K) =L= WETPCT*YLDKG("WET",K)*PRDN("WET") ;
WOODSELL(K)..SELL("WOOD",K) =L= WOODSOLD ;
TOTLAB .. labagr + labwood =L= MLABSUP;
AGRLAB .. labour("WET")*PRDN("WET") + labour("DRY")*PRDN("DRY") - HL =L= labagr;
WOODLAB .. labour("WOOD")*PRDN("WOOD") =L= labwood;
DPOWER .. sum(J, DRAFT(J)*PRDN(J)) =L= DRAFTAVAIL + DL ;
KON(J,K) .. CON(J,K) =E= YLDKG(J,K)*PRDN(J) + BUY(J,K) - SELL(J,K) ;
INCOME1 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"1"))+MDOMEXP1 =L= sum(J, SELLPRI(J,"10")*SELL(J,"1"));
INCOME2 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"2"))+MDOMEXP2 =L= sum(J, SELLPRI(J,"10")*SELL(J,"2"));
INCOME3 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"3"))+MDOMEXP3 =L= sum(J, SELLPRI(J,"10")*SELL(J,"3"));
INCOME4 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"4"))+MDOMEXP4 =L= sum(J, SELLPRI(J,"10")*SELL(J,"4"));
INCOME5 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"5"))+MDOMEXP5 =L= sum(J, SELLPRI(J,"10")*SELL(J,"5"));
INCOME6 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"6"))+MDOMEXP6 =L= sum(J, SELLPRI(J,"10")*SELL(J,"6"));
INCOME7 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"7"))+MDOMEXP7 =L= sum(J, SELLPRI(J,"10")*SELL(J,"7"));
```

```
INCOME8 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"8"))+MDOMEXP8 =L= sum(J, SELLPRI(J,"10")*SELL(J,"8"));
INCOME9 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"9"))+MDOMEXP9 =L= sum(J, SELLPRI(J,"10")*SELL(J,"9"));
INCOME10 .. sum(J, VC(J)*PRDN(J))+(WAGEH*HL)+PDL*DL+sum(J,
BUYPRI(J,"10")*BUY(J,"10"))+MDOMEXP10 =L= sum(J, SELLPRI(J,"10")*SELL(J,"10"));
GPRODVAL .. GVALUE =E= SELLPRI("wet","10")*YLDKG("wet","10")*PRDN("wet") ;
DPRODVAL .. DVALUE =E= SELLPRI("dry","10")*YLDKG("dry","10")*PRDN("dry") ;
WPRODVAL .. WVALUE =E= SELLPRI("wood","10")*YLDKG("wood","10")*PRDN("wood") ;

option nlp=minos5;
MODEL UTILITY1 / ALL / ;
utility1.optfile = 1;
option limcol = 0;
option decimals =  8;

set iter / i1*i1000 /;
Parameter Rep(Iter,*);
loop(iter,
LAMBDA1 = LAMBDA1 + 0.0001 ;

SOLVE UTILITY1 USING NLP MAXIMIZING Z1 ;
RA1 = (SQR(A1)*EXP(-A1*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*SQR(B1)*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A1*EXP(-
A1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*B1*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RR1 = RA1*31699.8543;
DEVSQ = SQR(GVALUE.L-WETOBS)+SQR(DVALUE.L - DRYOBS)+SQR(WVALUE.L -
WOODOBS);
Rep(Iter,'Devsq') = devsq;
Rep(Iter,'Lambda1') = lambda1;
Rep(Iter,'COARA')  = ra1;
Rep(Iter,'CORRA')  = rr1;
Rep(Iter,'wetacre')  = prdn.l("wet");
Rep(Iter,'dryacre')  = prdn.l("dry");
Rep(Iter,'wetkg')  = wetprkg.l;
Rep(Iter,'drykg')  = dryprkg.l;
Rep(Iter,'woodhr')  = labwood.l;
Rep(Iter,'agrhr')  = agrlab.l;
Rep(Iter,'totalhr')  = totlab.l;
Rep(Iter,'hirelab')  = hl.l;
Rep(Iter,'hiredr')  = dl.l;
Rep(Iter,'wetcon10')  = con.l("wet","10");
Rep(Iter,'drycon10')  = con.l("dry","10");
Rep(Iter,'woodcon10')  = con.l("wood","10");
Rep(Iter,'wetsell10')  = sell.l("wet","10");
Rep(Iter,'drysell10')  = sell.l("dry","10");
Rep(Iter,'woodsell10')  = sell.l("wood","10");
Rep(Iter,'wetbuy10')  = buy.l("wet","10");
Rep(Iter,'drybuy10')  = buy.l("dry","10");
Rep(Iter,'woodbuy10')  = buy.l("wood","10");
Rep(Iter,'utils')  = Z1.l);

$libinclude xldump rep mrep1sn99y.wc50.gc50.9.50.xls
display rep;
```

A4 Tri-Sector Model With Three Risk Parameters for Wealth Quartile 1

This section provides a listing of programming changes that are needed to enable the tri-sector model with a single risk parameter to accommodate three risk parameters.

```
SCALARS

LAMBDA1      gardens risk aversion parameter  / 0.0 /
LAMBDA2      dryland risk aversion parameter  / 0.0 /
LAMBDA3      woodlands risk aversion parameter  / 0.0 /
A1           value of COARA when LAMBDA1=0  / 0.0000035051 /
B1           value of COARA when LAMBDA1 approaches infinity / 0.000421 /
A2           value of COARA when LAMBDA2=0  / 0.0000035051 /
B2           value of COARA when LAMBDA2 approaches infinity / 0.000421 /
A3           value of COARA when LAMBDA3=0  / 0.0000035051 /
B3           value of COARA when LAMBDA3 approaches infinity / 0.000421 /
RA1          "gardens coefficient of absolute risk aversion"
RR1          "gardens coefficient of relative risk aversion"
RA2          "dryland coefficient of absolute risk aversion"
RR2          "dryland coefficient of relative risk aversion"
RA3          "woodlands coefficient of absolute risk aversion"
RR3          "woodlands coefficient of relative risk aversion"

OBJECTIVE1 .. Z1 =E= 1000*(sum(K,PROBK*(-EXP(-A1*SUM(J,CONPRI(J,K)*CON(J,K)))-
LAMBDA1*EXP(-B1*SUM(J,CONPRI(J,K)*CON(J,K)))))+sum(K,PROBK*(-EXP(-
A2*SUM(J,CONPRI(J,K)*CON(J,K)))-LAMBDA2*EXP(-
B2*SUM(J,CONPRI(J,K)*CON(J,K)))))+sum(K,PROBK*(-EXP(-
A3*SUM(J,CONPRI(J,K)*CON(J,K)))-LAMBDA3*EXP(-B3*SUM(J,CONPRI(J,K)*CON(J,K))))));

option nlp=minos5;
MODEL UTILITY1 / ALL / ;
utility1.optfile = 1;
option limcol = 0;

set iter1 / i1*i10 /;
ALIAS (ITER1, ITER2, ITER3);
Parameter Rep(Iter1,Iter2,Iter3,*);
* loop for each lambda1 for each lambda2
loop(iter1,
LAMBDA1 = LAMBDA1 + 0.01;
lambda2 = 0;
* loop for each lambda2 for each lambda3
     loop(iter2,
     LAMBDA2 = LAMBDA2 + 0.01;
     lambda3=0;
* loop for each lambda3
          loop(iter3,
          LAMBDA3 = LAMBDA3 + 0.01;
  display '+++++ ', lambda1, ' ', lambda2, ' ', lambda3;
```

```
SOLVE UTILITY1 USING NLP MAXIMIZING Z1;
RA1 = (SQR(A1)*EXP(-A1*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*SQR(B1)*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A1*EXP(-
A1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA1*B1*EXP(-
B1*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RA2 = (SQR(A2)*EXP(-A2*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA2*SQR(B2)*EXP(-
B2*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A2*EXP(-
A2*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA2*B2*EXP(-
B2*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RA3 = (SQR(A3)*EXP(-A3*SUM(J, CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA3*SQR(B3)*EXP(-
B3*SUM(J,CONPRI(J,"10")*CON.L(J,"10"))))/(A3*EXP(-
A3*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))+LAMBDA3*B3*EXP(-
B3*SUM(J,CONPRI(J,"10")*CON.L(J,"10")))) ;
RR1 = RA1*31699.8543;
RR2 = RA2*31699.8543;
RR3 = RA3*31699.8543;
DEVSQ = SQR(GVALUE.L-WETOBS)+SQR(DVALUE.L - DRYOBS)+SQR(WVALUE.L -
WOODOBS);
Rep(Iter1,Iter2,Iter3,'Devsq') = devsq;
Rep(Iter1,Iter2,Iter3,'Lambda1') = lambda1;
Rep(Iter1,Iter2,Iter3,'Lambda2') = lambda2;
Rep(Iter1,Iter2,Iter3,'Lambda3') = lambda3;
Rep(Iter1,Iter2,Iter3,'COARA1')  = ra1;
Rep(Iter1,Iter2,Iter3,'COARA2')  = ra2;
Rep(Iter1,Iter2,Iter3,'COARA3')  = ra3;
Rep(Iter1,Iter2,Iter3,'CORRA1')  = rr1;
Rep(Iter1,Iter2,Iter3,'CORRA2')  = rr2;
Rep(Iter1,Iter2,Iter3,'CORRA3')  = rr3;
Rep(Iter1,Iter2,Iter3,'wetacre')  = prdn.l("wet");
Rep(Iter1,Iter2,Iter3,'dryacre')  = prdn.l("dry");
Rep(Iter1,Iter2,Iter3,'wetkg')  = wetprkg.l;
Rep(Iter1,Iter2,Iter3,'drykg')  = dryprkg.l;
Rep(Iter1,Iter2,Iter3,'woodhr')  = labwood.l;
Rep(Iter1,Iter2,Iter3,'agrhr')  = agrlab.l;
Rep(Iter1,Iter2,Iter3,'totalhr')  = totlab.l;
Rep(Iter1,Iter2,Iter3,'hirelab')  = hl.l;
Rep(Iter1,Iter2,Iter3,'hiredr')  = dl.l;
Rep(Iter1,Iter2,Iter3,'wetcon10')  = con.l("wet","10");
Rep(Iter1,Iter2,Iter3,'drycon10')  = con.l("dry","10");
Rep(Iter1,Iter2,Iter3,'woodcon10')  = con.l("wood","10");
Rep(Iter1,Iter2,Iter3,'wetsell10')  = sell.l("wet","10");
Rep(Iter1,Iter2,Iter3,'drysell10')  = sell.l("dry","10");
Rep(Iter1,Iter2,Iter3,'woodsell10')  = sell.l("wood","10");
Rep(Iter1,Iter2,Iter3,'wetbuy10')  = buy.l("wet","10");
Rep(Iter1,Iter2,Iter3,'drybuy10')  = buy.l("dry","10");
Rep(Iter1,Iter2,Iter3,'woodbuy10')  = buy.l("wood","10");
Rep(Iter1,Iter2,Iter3,'utils')  = Z1.l;
);
);
);
$libinclude xldump rep am1sn99y.wc50.gc50.9.50.xls
display rep;
```

APPENDIX B

Methods Used to Calculate Base Values for Parameters Used in Household Models

This appendix presents details on methods used to calculate parameters for the household models. Data obtained from the survey were very disaggregated. Within each wealth quartile, these data were then aggregated by sector for use in the models. While problems were encountered in aggregating data (e.g., sectors such as woodlands were made up of a large and complex basket of diverse activities), aggregation was necessary in order to conform to the structure of model used in this study.

B1.1 Choosing Between Two Methods for Aggregating Household Data

Two methods, each with the potential to produce different results, were considered for use in calculating base values for key parameters such as costs, yields and prices for each wealth group The first method derived the values for each parameter as a mean of average household data. For example, prices per wealth quartile were derived by first calculating a mean price for each household. Next, the average of these means was calculated over all households (Table B.1, Method I). In this case, the mean of the observation for each household carried an equal weight in calculating an overall average for all households within a wealth category. Table B.1 (Method I) provides values of the parameters that were calculated using the first method.

In the second method, mean values for the parameters were calculated over all observations regardless of how many observations were derived from each household (Table B.1, Method II). Aggregate household prices for each sector, for example, were obtained by dividing the total value of production (in Z$), summed over all households in a wealth quartile, by the total weight of production (in kilograms) for those households. A similar method was used for calculating costs and yield for each wealth quartile. This procedure implicitly gave greater weighting to households with greater production and/or greater numbers of observations. For example, a household using one acre for dryland agriculture production would be given a higher weighting, in terms of contributing to average yield, compared to a household using 0.6 acres for dryland agriculture production.

Table B.1 shows that there can be substantial differences between values calculated using the two different methods. Therefore, there was a need to decide on which method was to be used. Given that each household had the potential to have multiple observations, the use of Method II allowed for the use of more information. Results obtained using the second method were therefore selected for the analysis since they were deemed to be more informative.

B1.2 Choice of Parameters Used in Models

The next step was to select values of the parameters that were to be used in modelling. In examining the results from Method II provided in Table B.1, it was evident that some parameters varied substantially by wealth quartile while others displayed little variability across quartiles. The results obtained for dryland agriculture and garden sector costs and yields demonstrated a fairly consistent similar pattern of increased values with increased wealth (Table B.1). That is, wealthier households tended to yield more per acre and had higher costs as well. However, there was little variation in woodlands yields and costs by wealth quartile. Moreover, Table B.1 shows that variable costs for woodlands were close to zero. These results arose because 75% of the observations had variable costs of zero and the values for remaining observations were small.

Table B.2 presents the values that were actually chosen to use in the models as derived from the information in Table B.1. For dryland agriculture and garden sectors, where the results showed a general increase in values of yields and costs as wealth increased, the average values from Method II were used for each wealth sector. For woodland yields, there was no discernable pattern across wealth groups, so a rounded average of 8.5 kg/hour was used. For prices, where there was little variability, a rounded average was used. Finally, because woodland variable costs were so low, with a mode of zero, these costs were set equal to zero in the models.

In order to test for consistency among the derived information between sectors, Table B.2 also shows calculated estimates for the return per hour of labour in each of the three sectors. For dryland agriculture and gardens, return per hour of labour was calculated by dividing net return (i.e., the gross return minus non-labour costs per acre, Table B.2, Column 4) by labour requirements per acre (Table B.2, Column 5). Within these two sectors, values range from Z$1.51/hour to Z$3.11/hour. However, if the average woodland price of Z$0.5/kg (suggested by the data) is used, the resulting return to labour is Z$4.26/hour. This is significantly higher than values for the other sectors. A woodlands price of Z$0.50/kg would make it attractive for households to divert a large proportion of their resources (i.e., labour) to the woodlands sector. Because this value was substantially beyond the range of values found in the other sectors, the values of the woodland prices calculated from the data were questioned. A thin market for woodlands existed given that there was no national market for woodlands. Thus woodlands prices collected during the survey were mainly market prices based on local transactions. The amount of woodland products that could be absorbed by the local markets was limited. The non-clearing nature of the thin market for woodlands implied that there was a chance of having woodlands prices that were distorted. For these reasons, it was decided to adopt a woodland price of Z$0.25/kg. This value resulted in a return to labour of Z$2.13/hour which lies within the range for other sectors.

Table B.1 Variable Costs, Yield and Prices Calculated Using Two Methods[a]

Sector/Wealth Quartile	Variable Costs, Z$/acre		Yield, kg/acre		Price, Z$/kg	
	Method I	Method II	Method I	Method II	Method I	Method II
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Dryland Agriculture						
Lowest 25%	201.86	172.58	521.97	403.21	5.30	5.11
25-50%	262.45	187.04	475.81	387.28	5.54	5.57
50-75%	276.57	218.08	516.80	464.04	5.84	5.87
Top 25%	445.98	342.36	858.38	675.33	6.16	6.28
Average	297.28	240.78	593.60	499.41	5.71	5.87
Gardens						
Lowest 25%	136.95	104.77	752.71	623.24	6.22	6.70
25-50%	199.95	186.81	675.24	656.55	6.05	6.88
50-75%	211.44	158.83	825.67	762.32	5.85	6.71
Top 25%	382.85	316.42	1289.33	1253.12	6.32	7.20
Average	235.93	194.96	886.41	841.39	6.12	6.94
Woodlands	**Z$/hour**		**kg/hour**		**Z$/kg**	
Lowest 25%	0.01	0.01	19.09	8.76	0.55	0.51
25-50%	0.14	0.14	14.82	7.59	0.61	0.54
50-75%	0.10	0.07	14.51	8.76	0.47	0.47
Top 25%	0.29	0.15	19.78	10.36	0.47	0.47
Average	0.13	0.09	17.04	8.79	0.53	0.50

Notes:

a. Method I values were calculated using means of individual household data. Method II values were calculated using aggregated household data.

Table B.2 Variable Costs, Yields and Prices Used in Household Models

Sector/Wealth Quartile	Variable Costs [a]	Yield [b]	Price [c]	Net Return [d]	Labour Requirement [e]	Return per Hour of Labour [f]
	Z$/acre	kg/acre	Z$/kg	Z$/acre	Hours/acre	Z$/hour
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Dryland Agriculture						
Lowest 25%	172.58	403.2	5.5	2045.08	1196.5	1.71
25-50%	187.04	387.3	5.5	1943.00	1035.1	1.88
50-75%	218.08	464.0	5.5	2334.14	1061.4	2.20
Top 25%	342.36	675.3	5.5	3371.96	1083.1	3.11
Gardens						
Lowest 25%	104.77	623.2	6.0	3634.67	1643.3	2.21
25-50%	186.87	656.6	6.0	3752.49	2481.6	1.51
50-75%	158.83	762.3	6.0	4415.09	2206.5	2.00
Top 25%	316.42	1253.1	6.0	7202.30	2493.1	2.89
Woodlands	**Z$/hour**	**kg/hour**	**Z$/kg**	**Z$/hour**	**Hours**	**Z$/hour**
Lowest 25%	0	8.5	0.25	2.13	1	2.13
25-50%	0	8.5	0.25	2.13	1	2.13
50-75%	0	8.5	0.25	2.13	1	2.13
Top 25%	0	8.5	0.25	2.13	1	2.13

Notes:

a. Variable costs (less labour costs) for dryland agriculture and gardens were derived from Table B.1, Column 2. Woodlands variable costs were set to zero since 75% of the observations had variable costs of zero and remaining values were small.

b. Yields for dryland agriculture and gardens were derived from Table B.1, Column 4. A mean woodlands yield of 8.5 kg/hour was calculated using data for Method II and was applied to all wealth quartiles.

c. Average prices of Z$5.5/kg, Z$6.00/kg and $0.50/kg were calculated for dryland agriculture, gardens and woodlands using price data in Table B.1. There was not much variation in prices calculated using the two methods. A woodlands price of Z$0.25/kg was selected in order to ensure that resources were not all allocated to woodlands.

d. Net returns per acre (or per hour for woodlands) were calculated as the difference between the gross return (price* yield) per acre (or per hour for woodlands) and the cost per acre (or cost per hour for woodlands).

e. Labour requirements per acre were derived by dividing total time use in adult equivalent hours by the total acreage planted per wealth quartile. An implicit labour requirement coefficient of one was specified for the woodlands activity since the activity was measured in terms of hours spent harvesting.

f. Net returns per hour of labour for each sector and wealth quartile were calculated by dividing the net return values (Column 4) by the labour requirement values (Column 5).

APPENDIX C

Computation of Household Yield and Price Series

This appendix provides details on how base values for yields and prices were extended to form household yield and price series by sector over ten states of nature. The appendix starts by describing procedures used to derive household yield series by sector. This is followed by a description of procedures used to derive household price series.

C1 Yield Series

Yield series by sector in each state of nature were necessary for parameter YLD_{jk} in equation 3.3-2. However, there were no historical household level yield series available for dryland agriculture, gardens and woodlands sectors. Therefore, it was necessary to create a time series of yields for the 10 states of nature. Yields were calculated for each wealth quartile in order to capture differences in production technology or management practice that could be attributable to wealth. Aggregate household yields (kg/acre for crops and kg/hour for woodlands) derived from Table B.2 (Column 2) were used to derive yield series. These aggregate household yields were used as the values for state of nature 10. Values for the other nine states of nature were derived from this base value. The following sections describe how base values of yields were extrapolated to form yield series.

C1.1 Dryland Agriculture Yield Series

Ideally, a time series of dryland agriculture yield data would have been used for the other nine states of nature, but the necessary household data were not available. Instead, the relative variability in a time series of aggregate yields at a district level for four local grains (maize, sorghum, rapoko and mhunga) was used to extend the aggregate household yield for the full set of locally grown dryland crops (calculated from survey data) into a time series at the household level (Table C.1).

The data for the four grain crops (maize, sorghum, rapoko and mhunga) constituted only a subset of all locally grown dryland crops, but they did represent the main types of grains grown in the communal areas. The goal was to transfer the degree of variability in yields for the four grains at the district level to the yields for the full set of household dryland crops. The implicit assumption was that the yields of the four grains, for which ten years of data were available, had similar year-to-year variation as the yields for the full set of locally grown dryland crops. It was felt that this assumption was justified on the basis that both were affected by similar environmental conditions. The weighting attached to the yield for each of the four grain crops was the relative contribution that each made to the total weight in kilograms for the four grains at district level.

A yield variability index (Table C.1, Column 2) for dryland agriculture was created by dividing the annual grains yield for Chivi District (Table C.1, Column 1) in each state of nature[54] by the yield for the base year (1996). The household yield series for dryland agriculture (Table C.1, Column 3) was created by multiplying the base year aggregate household yield value for each wealth quartile (Table B.2, Column 2; for wealth quartile 1 this is 403.21kg/acre) by values of the yield index for dryland agriculture in each state of nature. Table C.1 (Column 3) provides the resulting household yield series for dryland agriculture for wealth quartile 1, as an example. Table 4.16[55] provides the household yield series for dryland agriculture by wealth quartile and state of nature.

C1.2 Gardens Yield Series

Ideally, household garden yield data would have been used to calculate yields for the other nine states of nature, but the historical household data were not available. A household garden yield series was created through the use of two key assumptions. First, it was assumed that the general pattern of garden yields at the household level would mimic the historical pattern of national yields for a similar set of crops. In this case, the data used were national time series yields for melons and vegetables. However, it was recognized that the degree of year-to-year variability of yields at the national level probably underestimates the yield variability at the household level. Thus, the second key assumption was that the relationship between national and household garden yield variability (i.e., relative variability) was similar to that for a crop for which national and

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54 The years 1987-1996 correspond to states of nature 1-10 respectively.
55 Tables without letters are located in thesis chapters.

household yields were available; specifically dryland agriculture yields (proxied by maize at the national level).

The following procedures were undertaken in deriving household garden yield series by wealth quartile. First, national maize, and vegetable and melons yield series data (Table C.2, Columns 1 and 2) obtained from the Food and Agricultural Organization (FAO) data set were detrended (Table C.2, Columns 3 and 4). Detrending was done to eliminate the contribution of a time trend towards the variability in the FAO yield data sets (1961-2001) so that only year-to-year variability remained. The detrending procedure was carried out as follows. Separate ordinary least squares regressions were run with the dependent variables being national vegetables and melons yields, and maize yields. The independent variables were time, time-squared, dummy variables for time, and interactions of time and dummy variables for time. Dummy variables for time were included to check whether the time trend variable was significant in split time periods of the yield series. Variables with statistically insignificant coefficients were dropped and another regression done to obtain the predicted national yield series for vegetables and melons, and maize that did not have a time trend. T-test values were used for identifying statistically significant variables while R-squared values were used to evaluate the overall goodness of fit of the models. Significant variables for the national vegetables and melons detrending process were dummy variables for time and one interaction of time and dummy variable for time. This result suggested that the earlier portion of the vegetables and melons yield data set did not have a significant time trend. Thus detrending for the vegetables and melons data set was only done for the later segment of the data set. Significant variables for detrending the national maize yield series were time and time squared variables.

Second, the relationship between variability in national maize and household dryland agriculture yield series was derived. The coefficient of variation for maize at the national level, using detrended yields, was approximately 0.42 (Table C.2, Column 3) while that for dryland agriculture at district (and therefore household) level was approximately 0.66 (Table C.1, Column 1). It was assumed that an equivalent relative relationship between national and household yields held for vegetables and melons since both dryland agriculture and garden crops were affected by the similar environmental conditions. An adjustment factor for the variation between the district and national dryland agriculture historical yield data was obtained by dividing the CV value for local district grains yield by the CV value for national maize.

$$(C.1) \quad CVFACTOR = (CVLOCAL)/(CVFAO)$$

where CVFACTOR is an adjustment factor, CVLOCAL is the CV% for Chivi District grains data and CVFAO is CV% for the detrended national maize yield data obtained from the FAO data base. The value of the factor was 1.6, that is, 0.66/0.42. In other words, it is assumed that household yields are 160% as variable as national yields. The degree of variability in national "garden" yields was increased by a factor consistent with the relative variability in maize/dryland agriculture yields.

Third, deviations from the mean of the detrended vegetables and melons yield values (Table C.2, Column 5) were then adjusted to reflect household conditions for each year. The deviations were multiplied by the adjustment factor (CVFACTOR) and then added to the mean yield for vegetables and melons data to obtain a new "adjusted" vegetable and melons yield data series that reflected the greater variability in household yields (Table C.2, Column 6). The adjustment formula was as follows:

$$(C.2) \quad ADYLD = (DEV * CVFACTOR) + \overline{YLD}$$

where ADJYLD is vegetable and melons yield adjusted to reflect household variables, DEV is the deviation from the mean of the vegetables and melons yield data at the national level and $\overline{YLD}$ is the mean national yield for vegetables and melons data calculated over all 10 years.

Fourth, a yield index for vegetables and melons (Table C.2, Column 8) was created by dividing the "household" yields for vegetables and melons for each year (Table C.2, Column 7) by the value of the "household" yield series in the base year (1996). Finally, household garden yield series for each wealth quartile were created by multiplying the aggregate household garden yield (Table B.2, Column 2; for wealth quartile 1 this is 623.24kg/acre), calculated from household survey data, by the values of the yield index for vegetables and melons in each state of nature (Table C.2, Column 8). Table C.2 (Column 9) provides the household garden yield series for wealth quartile 1, as an example. Table 4.17 provides the household garden yield series by wealth quartile for each state of nature. The derived household garden yield series (Table C.2, Column 9) has the same CV% of 3.21 as the national vegetables and melons yield series adjusted for relative variability between national and household level dryland agriculture yields (Table C.2, Column 7).

C1.3 Woodlands Yield Series

Ideally, household time series of woodlands yield data would have been used for the other nine states of nature, but the household data were not available. As a first step, the household woodlands yield series were created by imposing an equivalent degree of relative variability on the household woodlands yields as was present in the household yields for dryland agriculture, using the aggregate household woodlands yield for state of nature 10 as the base. Then, expert opinion was then used to adjust variability in woodland yields relative to that for dryland agriculture.

The following sequence of steps was taken in deriving a household woodlands yield series. First, the index for dryland agriculture from Table C.1 (Column 2) is reproduced in Table C.3 Column 1. It was assumed that dryland agriculture yields and woodlands yields would have a similar pattern (not magnitude) of variability given that both were affected by similar climatic conditions. Second, the deviation in the index for dryland agriculture yields from the mean was calculated for each year (Table C.3, Column 2). Third, the deviation of the dryland agriculture yield index from the mean was adjusted to reflect relative variability in dryland agriculture to woodlands (Table C.3, Column 3). This adjustment was based on expert opinion that suggested that values of output for dryland agriculture were 10 times as variable as those for woodlands. The deviations in woodlands yields were adjusted using this relative variability factor, resulting in lower absolute values for the deviations. The formula used to compute the adjustment factors in each state of nature (k) is illustrated below.

$$(C.3) \quad ADJUSTMENT\ FACTOR = (YDEV * YRATING)/(YBASEOBS / YMEAN)$$

where YDEV is the deviation from the mean of the yield index for dryland agriculture (Table C.3, Column 2), YRATING is the value of the index of variability of woodlands values of output relative to that for dryland agriculture, YBASEOBS is the base value of the yield index for dryland agriculture in 1996 (i.e., 1 in Table C.3, Column 1), and YMEAN is the average value of the yield index for dryland agriculture (i.e., 0.73 in Table C.3, Column 1).

Fourth, the revised deviation (Table C.3, Column 3) was added to the base value of the yield index for dryland agriculture in 1996 (i.e., 1 in Table C.3, Column 1) to get a yield index for woodlands (Table C.3, Column 4). Lastly, the household yield series for woodlands for each of the ten years were created by projecting the base year aggregate household woodlands yield value of 8.5kg/hour (in Table B.2, Column 2), calculated from the household survey data, according to the variation in the yield index for woodlands (Table C.3, Column 4). As an example, the formula to calculate the household woodlands yield value for 1995 (y9) was as follows:

$$(C.4) \quad y9 = y10 * (I9 / I10)$$

where y10 is the aggregate household woodlands yield in 1996 (i.e. 8.5kg/hour in Table B.2, Column 2), and I9 and I10 are values of the yield index for woodlands for 1995 and 1996 respectively. Table C.3 (Column 5) provides the household woodlands yield series that was applied to all wealth quartiles. The derived household woodlands yield series

(Table C.3, Column 5) has the same CV% of 6.59 as the woodlands yield index (Table C.3, Column 4).

C2 Price Series

Price data were collected in the household survey for cases where goods and services were sold by the sample households. Base year prices for dryland agriculture, gardens and woodlands were needed for each of the ten states of nature in this study for the purpose of valuing household production, consumption, sales and buying activities. Prices for each sector in each state of nature for consumption, sales and buying activities are represented by parameters P_{cjk}, P_{sjk} and P_{bjk} in equation 3.3. However, only a single year's observation of prices collected during the survey was available for use in this study. The approach adopted to overcome the lack of household historical price data was to create price series using the aggregate household single year prices, time series of national historical price data for some dryland crops[56] and a variability rating for output values based on expert opinion (Table 4.15).

The aggregate household prices for state of nature 10 for dryland agriculture, gardens and woodlands sectors were computed using price and production survey data for all products in each sector as explained in Appendix B. Table B.2 (Column 3) presents base values for prices that were used in this study. The procedures used in deriving household price series for dryland agriculture, gardens and woodlands sectors are explained below.

56 The basket of dryland crops for which national prices were available was a subset of the dryland crops grown locally.

C2.1 Dryland Agriculture Price Series

The single year's aggregate household price of Z$5.5/kg derived from Table B.2 (Column 3) was used to develop a household price series for dryland agriculture based on the national price series for dryland crops. In essence, variability around the base year observation in the national price series in proportion to the household prices was used to create a time series of ten household values for prices. The goal was to transfer year–to-year variability in national prices of dryland crops to household prices for dryland crops. Since household prices were not equal to national prices, there was a need to adjust to local conditions while maintaining proportional variability as demonstrated in the steps below.

The following steps were taken in the process of creating a household price series for dryland agriculture. First, real prices for a set of dryland crops with national producer prices were calculated. The crops used included maize, cotton, sorghum, groundnuts, finger millet, pearl millet and sunflower. Besides these crops, the set of household grown dryland crops from the survey also included roundnuts, sweet reed, rice, beans, and sweet potatoes. However, national prices for these crops were not available. Nominal producer prices for the crops with national prices were deflated using the consolidated Consumer Price Index with 1999 as the base year (i.e., 1999 CPI = 100). Adjustments were made to convert the CPI to a 1999 base year since most of the data collection for the study took place in 1999. CPI (1995=100) data were obtained from the Zimbabwe Central Statistical Office, and a conversion to CPI (1999=100) was then done. For example, the value of CPI for 1998 using CPI (1999=100) was calculated as follows:

(C.5) $CPI_{98} = (CPI_{9895}/CPI_{9995})*100$

where CPI_{98} is the CPI for 1998 based on CPI(1999=100) (i.e., 63.1 in Table C.4, Column 2); CPI_{9895} is the CPI for 1998 based on CPI(1995=100) (i.e., 190.1 in Table C.4, Column 1); and CPI_{9995} is the CPI for 1999 based on CPI (1995=100) (i.e., 301.3 in Table C.4, Column 1). Table C.4 (Column 2) provides the CPI (1999=100) series.

Real prices for each crop by year were calculated using the following formula:

(C.6) $RP_i = (CPI_{99}/CPI_i) * NP_i$

where RP_i is the real price in year i, CPI_{99} is the base value of CPI(1999=100), that is, 100, CPI_i is the CPI index for year i, and NP_i is the nominal (current producer) price for year i. Table C.5 provides real prices for the set of national dryland crop prices.

Second, the proportion that each of the crops with national prices contributed in value terms to the "basket" grown locally (excluding crops for which national prices were not available) was assessed (Table C.6). The percentage contributions of each crop to the total value of production for that sub-set of dryland crops were then multiplied by the deflated national price series to calculate a weighted average national dryland price series for each year[57] (Table C.7, Column 7). The weighted average national dryland price series was obtained as a horizontal summation of the weighted values contained in Table C.7.

57 Sunflowers were dropped because that crop had a weighting of zero percent.

Third, the weighted average national dryland price series (Table C.7, Column 7) was then detrended to ensure that only "normal" year-to-year variability was reflected in the price series (Table C.8, Column 1). The procedures followed in detrending included running an ordinary least squares regression with values of the national price series for dryland crops as the dependent variable and time, and a dummy for time variable as explanatory variables. The coefficient for the time variable was not statistically significant and the variable was dropped. T-test values were used for identifying statistically significant variables while R-squared values were used to evaluate the overall goodness of fit of the models. Another regression was done with the dummy for time variable as the explanatory variable to obtain the predicted national price series for dryland agriculture that did not have a time trend. The predicted values of the national price series for dryland crops were derived and their deviation from the "observed" national price series obtained. Deviations between predicted and observed national prices for dryland crops for each year were added to the predicted value of the price series in the base year (1996) to obtain a detrended national price series for dryland agriculture (Table C.8, Column 1).

Fourth, a national price index for dryland crops (Table C.8, Column 2) was created by dividing the detrended national price series for dryland crops (Table C.8, Column 1) for each year by that for the base year (1996). The household price series for dryland agriculture (Table C.8, Column 3) was created by multiplying the base year aggregate household price of Z$5.5/kg (in Table B.2, Column 3) by the national price index for dryland agriculture for each year. It was assumed that national price variability was the same as local price variability since the market for dryland agriculture products was national in nature. Table C.8 (Column 3) provides the household price series for dryland agriculture that was applied to all wealth groups.

C2.2 Gardens Price Series

Unlike dryland agriculture prices, there were no national price series available for garden commodities. Therefore the household garden price series was created by using the pattern of variability in the household price series calculated for dryland agriculture, adjusted for expert opinion (Table 4.15) regarding the variability of values of output for gardens relative to that for dryland agriculture. The basic process involved creating an index of national dryland agriculture prices (base year index = 1). Deviations from the mean value of the index were then calculated and adjusted for expert opinion regarding the relative variability noted earlier. These adjusted deviations were then used to create an index of garden prices. The indices are multiplied by the base aggregate household garden price to obtain the garden price series.

The garden price series that was originally derived using this method resulted in problems with respect to the degree of variability in value of production[58]. Specifically, the value of garden output (price multiplied by quantity) for the ten states of nature was only 5% as variable as the value of dryland agriculture output. Expert opinion suggested that the value of garden output was 25% as variable as that for dryland agriculture (Table 4.15). This result suggested that a greater year-to-year variability in garden prices was required in order to attain a level of variability in the values of output consistent with

58 Dryland agriculture and woodlands sectors did not suffer from this problem.

expert opinion. It was calculated that garden prices needed to be 2.7 times as variable as dryland agriculture prices to accomplish this result. This relative variability made sense given the lack of ability to store garden produce, which contributes to higher garden price variability. Moreover, basing garden prices on dryland prices might not be entirely appropriate since dryland agriculture prices were more stable because of government controls.

The following sequence of steps was taken in deriving a household garden price series. First, the dryland crop price index derived in Section C2.1was used as an initial basis for calculating the household garden price series. Given the nature of markets for gardens, it was thought that some of the same factors that affect the household dryland agriculture price, such as climatic conditions, would affect garden prices as well.

Deviations of the dryland crop price index from the average index value were then calculated for each year (Table C.8, Column 4). These deviations were then adjusted to reflect relative variability in dryland agriculture to gardens (Table C.8, Column 5). This adjustment was based on the fact that garden prices had to be 2.7 times as variable as dryland prices, as discussed earlier. The formula used to adjust the deviations was:

$$(C.7) \quad ADJUSTED\,DEVIATION = (PDEV * PRATING)/(PBASEOBS\,/\,PMEAN)$$

where PDEV is the deviation from the mean of the price index for dryland agriculture (Table C.8, Column 4), PRATING is the value of the index of variability of garden values of output relative to that for dryland agriculture (i,e., 2.7), PBASEOBS is the base value of the price index for dryland agriculture in 1996 (i.e., 1.00 in Table C.8, Column 2), and PMEAN is the average value of the price index for dryland agriculture (i.e., 0.92 in Table C.8, Column 2).

The revised deviation (Table C.8, Column 5) was added to the base value of dryland agriculture price index (i.e., 1.00 in Table C.8, Column 2) to get an index for garden prices (Table C.8, Column 6). Lastly, the index for garden prices was applied in the manner shown below to the base garden price of Z$6.00/kg (in Table B.2, Column 3) derived from household survey data to get a household garden price series that was applied to all wealth quartiles. For example, the formula to calculate the household garden price value for 1995 (p9) is as follows:

$$(C.8)\ \ p9 = p10 * (i9 / i10)$$

where p10 is the aggregate household garden price for 1996 (i.e., the base state of nature price), and i9 and i10 are values of the index for garden prices for 1995 and 1996. Garden prices for the other years were derived in a similar manner. Table C.8 (Column 7) provides the household garden price series. The derived household garden price series (Table C.8, Column 7) has the same CV% of 16.34 as garden price index (Table C.8, Column 6).

Table C.9 and Table C.10 provide values of output and coefficients of values of output for gardens relative to that for dryland agriculture after adjusting garden price variability. The relative variability of garden values of output to that for dryland agriculture was 25% (as derived from expert opinion) after adjusting garden price variability (Table C.10).

C2.3 Woodlands Price Series

As with gardens prices, there were also no national price series available for woodlands. Therefore household woodlands price series were created by using the variation in the price series calculated for dryland agriculture, adjusted for expert opinion (Table 4.15). As explained in Appendix B, an aggregate household woodlands price of Z$0.25/kg was selected and applied to all wealth groups. The same process used to generate garden price series was applied and used to generate a household woodlands price series. However, there was no need to further adjust the variability of woodlands prices (as was needed for garden prices) since the variability of values of output for woodlands relative to dryland agriculture reflected the relative variability obtained from expert opinion (Table 4.15). The ratio of the CV for the household woodland price series to that for dryland agriculture was 10%. Table C.11 (Column 5) provides the household woodlands price series. The derived household woodlands price series (Table C.11, Column 5) has the same CV% of 0.61 as the woodlands price index (Table C.11, Column 4).

Table C.1 Household Dryland Agriculture Yield Series for Wealth Quartile 1

State of Nature	Year	Chivi District Grains Yield[a], kg/ha	Yield Index for Dryland Agriculture[b]	Household Dryland Agriculture Yield Series[c], kg/acre
		Column 1	Column 2	Column 3
1	1987	255.5	0.38	151.84
2	1988	990.1	1.46	588.38
3	1989	253.5	0.37	150.65
4	1990	876.0	1.29	520.58
5	1991	294.4	0.43	174.95
6	1992	18.2	0.03	10.82
7	1993	835.9	1.23	496.75
8	1994	405.1	0.60	240.74
9	1995	337.8	0.50	200.74
10	1996	678.5	1	403.21
	Average	494.5		293.9
	SD[d]	326.0		193.7
	CV%[e]	65.9		65.9

Notes:

a. Grains (maize, sorghum, rapoko and mhunga) data were obtained from Dr. Peter Frost, a Research Associate at the Institute of Environmental Studies (University of Zimbabwe). The data were originally from the Department of Agricultural, Technical and Extension Services (AGRITEX) Crop Production Estimates and was subsequently obtained from Famine Early Warning System (FEWS), Harare.

b. The yield index for dryland agriculture (Column 2) was calculated by dividing the yields (Column 1) for 1987-1996 by the yield for the base year (1996) in Column 1.

c. The household dryland agriculture yield series for wealth quartile 1 was calculated by multiplying the dryland agriculture yield index for each year (Column 2) by the base year (1996) dryland agriculture yield value of 403.21kg/acre in Table B.2, Column 2.

d. SD = Standard Deviation.

e. CV% = Coefficient of Variation as a percentage.

Table C.2 Derivation of Household Garden Yield Series for Wealth Quartile 1

Year	National Maize Yield[a], Hg/ha	National Vegetables and Melons Yield[a], Hg/ha	Detrended National Maize Yield[b], Hg/ha	Detrended National Vegetables and Melons Yield[b], Hg/ha	Deviation of Vegetables and Melons Yield Data from the Mean[c]	Column 5 Times Factor[d]	National Vegetables and Melons Yields Adjusted for Relative Variability of Dryland Agriculture Yields[e], Hg/Ha	National Vegetables and Melons Yield Index[f]	Household Garden Yield Series[g], kg/acre
	Column Number								
	1	2	3	4	5	6	7	8	9
1987	9173	66530	6632.6	74694.5	-906.71	-1409.93	74191.3	0.97	602.02
1988	18066	67151	15708.1	74732.3	-868.88	-1351.11	74250.1	0.97	602.50
1989	17079	67797	14928.6	74795.1	-806.06	-1253.42	74347.8	0.97	603.29
1990	17206	68805	15288.0	75219.9	-381.24	-592.82	75008.4	0.98	608.65
1991	14400	69646	12739.3	75477.8	-123.41	-191.91	75409.3	0.98	611.91
1992	4108	67810	2729.6	73058.6	-2542.59	-3953.72	71647.5	0.93	581.38
1993	16251	72211	15179.8	76876.4	1275.24	1982.99	77584.2	1.01	629.56
1994	16601	74800	15861.9	78882.2	3281.06	5102.05	80703.2	1.05	654.87
1995	5960	72400	5578.0	75899.1	297.88	463.21	76064.4	0.99	617.22
1996	16997	73460	16997.0	76375.9	774.71	1204.67	76805.8	1	623.24
Mean	13584.1	70061.0	12164.3	75601.18			75601.18		613.47
SD[h]	5178.35	2924.67	5157.5	1561.08			2427.47		19.70
CV%[i]	38.12	4.17	42.40	2.07			3.21		3.21

Notes:

a. Zimbabwe national maize, and vegetables and melons yield data (1987-1996) were obtained from the FAO statistical databases (http://apps.fao.org/). 1 hectogram (Hg) = 100 grams and 1 hectare (ha) = 2.471 acres.

b. Detrending was done to eliminate the contribution of a time trend towards the variability in the data set so that only normal year-to-year variability remained. Detrending of the national vegetables and melons data set (1961-2001) was only done from 1985 to 2001, as the earlier portion of the data set did not have a significant trend.

c. Deviations were obtained by subtracting the mean (75601.18 in Column 4) from each yield value in Column 4.

d. The value of the factor of relative variability between national and household level dyland agriculture yields was 1.6.

e. Yield values were derived by adding Column 6 data for each year to the mean yield for the detrended vegetable and melons yields, that is, 75601.18 in Column 5.

f. The yield index for vegetables and melons was created by dividing each yield value in Column 7 by the yield value for the base year, that is, 76805.8 Hg/ha.

g. The household garden yield series was created by multiplying Column 8 data for each year by the base year household yield value for gardens, that is, 623.24kg/acre for wealth quartile 1 in Table B.2 (Column 2).

h. SD = Standard Deviation.

i. CV% = Coefficient of Variation as a percentage.

Table C.3 **Woodlands Yield Series**

Year	Yield Index for Dryland Agriculture[a]	Deviation From Mean of the Dryland Agriculture Yield Index[b]	Deviation Adjusted for Relative Variability to Dryland Agriculture Yields[c]	Yield Index for Woodlands[d]	Derived Household Woodlands Yield Series[e], kg/hour
	Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**
1987	0.38	-0.35	-0.05	0.95	7.80
1988	1.46	0.73	0.10	1.10	9.02
1989	0.37	-0.36	-0.05	0.95	7.80
1990	1.29	0.56	0.08	1.08	8.83
1991	0.43	-0.30	-0.04	0.96	7.86
1992	0.03	-0.70	-0.10	0.90	7.41
1993	1.23	0.50	0.07	1.07	8.76
1994	0.60	-0.13	-0.02	0.98	8.05
1995	0.50	-0.23	-0.03	0.97	7.94
1996	1	0.27	0.04	1.04	8.50
Mean	0.73			1	8.20
SD[f]	0.48			0.07	0.54
CV%[g]	65.92			6.59	6.59

Notes:

a. The yield index for dryland agriculture was obtained from Table C.1, Column 2.
b. Deviations were obtained by subtracting the value of the mean of the dryland agriculture yield index (i.e., 0.73 in Column 1) from each value of the yield index (Column 1).
c. Column 3 contains deviations from the mean adjusted to reflect the fact that woodlands yields were 10% as variable as dryland agriculture yields as suggested by expert opinion (Table 4.15). These values were calculated using the following formula: (YDEV*YRATING)/(YBASEOBS/YMEAN) where YDEV is the deviation from the mean of the yield index for dryland agriculture (Column 2), YRATING is the value of the index of variability of woodlands values of output relative to that for dryland agriculture, YBASEOBS is the base year value of the yield index for dryland agriculture in 1996 (i.e., 1 in Column 1), and YMEAN is the average value of the yield index for dryland agriculture (i.e., 0.73 in Column 1).
d. The yield index for woodlands was obtained by adding Column 3 data for each year to the base year value of the dryland agriculture yield index (i.e., 1 in Column 1).
e. The base year yield value for woodlands was 8.5kg/hour (in Table B.2, Column 2). The formula used to calculate the household woodlands yield value for 1995 (y9) is as follows: y9 = y10*(I9/I10), where y10 is the aggregate household woodlands yield in 1996, and I9 and I10 are values of the yield index for woodlands in 1995 and 1996 respectively. Woodlands yields for the other years were derived in a similar way.
f. SD = Standard Deviation.
g. CV% = Coefficient of Variation as a percentage.

Table C.4 Consolidated Consumer Price Index (CPI)

Year	CPI (1995=100) [a]	CPI (1999=100) [b]
	Column 1	**Column 2**
1987	21.9	7.3
1988	23.5	7.8
1989	26.2	8.7
1990	29.8	9.9
1991	36.8	12.2
1992	52.3	17.4
1993	66.7	22.1
1994	81.6	27.1
1995	100	33.2
1996	121.4	40.3
1997	144.3	47.9
1998	190.1	63.1
1999	301.3	100.0

Notes:

a. Data were obtained from Central Statistical Office (CSO 2001).

b. CPI data (1995=100) was converted to CPI (1999=100) by dividing Column 1 data for each year by the CPI (1995=100) value for year 1999 and then multiplying the result by 100. The conversion to CPI(1999=100) was done by changing the base year from 1995 to 1999. For example, the value of CPI for 1998 using CPI(1999=100) was calculated as follows: $CPI_{98} = (CPI_{9895}/CPI_{9995})*100$ where CPI_{98} is the CPI for 1998 based on CPI(1999=100), that is, 63.1 in Column 2; CPI_{9895} is the CPI for 1998 based on CPI(1995=100), that is, 190.1 in Column 1; and CPI_{9995} is the CPI for 1999 based on CPI(1995=100), that is, 301.3 in Column 1. Column 2 provides the CPI(1999=100) series.

Table C.5 Real and Nominal Producer Prices for Dryland Crops, Z$/mt

Year	Maize		Cotton		Sunflower		Groundnut		Sorghum		Pearl Millet		Finger Millet	
	NP[a]	RP[a]	NP	RP	NP	RP	NP	RP	NP	RP	NP	RP	NP	RP
	Column Number													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1987	180	2476	800	11006	390	5366	900	12382	180	2476	250	4127	300	3439
1988	195	2500	850	10898	430	5513	1000	12821	195	2500	250	3846	300	3205
1989	215	2473	925	10638	455	5233	1000	11500	215	2473	250	3450	300	2875
1990	225	2275	117	1183	505	5106	1250	12638	225	2275	250	3033	300	2528
1991	270	2211	141	1154	580	4749	1250	10234	270	2211	260	2538	310	2129
1992	550	3169	301	1734	995	5732	1500	8641	550	3169	350	2016	350	2016
1993	900	4066	320	1446	1472	6649	1800	8131	520	2349	550	2349	520	2484
1994	900	3323	370	1366	1472	5435	2400	8862	520	1920	520	1920	520	1920
1995	1050	3164	420	1265	1500	4520	3500	10546	650	1958	520	1567	520	1567
1996	1200	2978	600	1489	1580	3921	5000	12409	920	2283	650	1613	650	1613

Notes:

a. NP = Nominal Price, RP = Real Price. Nominal producer prices were obtained from "The Agricultural Sector of Zimbabwe: Statistical Bulletin", (Ministry of Lands, Agriculture and Rural Resettlement 2000). Real price calculations were based on consolidated CPI with 1999=100 (Table C.4, Column 2). Real prices for each crop by year were calculated using the following formula: $RPi_i = (CPI_{99}/CPI_i)*NP_i$, where RP_i is the real price in year i, CPI_{99} is the CPI(1999=100), CPI_i is the CPI index for year i, and NP_i is the nominal (current producer) price for year i.

Table C.6 Value of Production (Z$) and Weights Attached to Dryland Crops Having National Prices

	Maize	Cotton	Sunflower	Groundnut	Sorghum	Pearl Millet (Rapoko)	Finger Millet	Total Value of Dryland Agriculture Production
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Value of Production[a]	900638.6	607896.7	4101.3	270024.9	82460.0	55954.0	29159.1	1950235
% Contribution to Value of Production[b]	46%	31%	0%	14%	4%	3%	1%	100%

Notes:

a. Values of production were obtained as the product of the kilograms produced and 5% trimmed mean prices derived from survey data. A five percent trimmed mean is the arithmetic mean calculated excluding the largest 5% and the smallest 5% of the cases. Eliminating the extreme cases from the computation of the mean results in a better estimate of central tendency, especially when the data are non-normal (SPSS Version 10). The value of production for each crop was calculated by adding the values of production for each household. The total value of production was calculated by adding the values of production for each crop.

b. The contribution of each crop to the total value of production was obtained by dividing the value of production for each crop by the total value of production for all crops. These contributions were then used as weights.

Table C.7 Calculations Used in Creating a National Price Series for Dryland Crops

Year	Crop						National Price Series for Dryland Crops[c], Z$/mt
	Maize	Cotton	Groundnuts	Sorghum	Peal Millet	Finger Millet	
	Percentage Contribution by Crop to Value of Production[a]						
	46	31	14	4	3	1	
	Product of Real Producer Price (Z$/mt) and % Contribution to Value of Production by Crop[b]						
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
1987	1139.2	3412.0	1733.5	99.1	123.8	34.4	6541.9
1988	1150.1	3378.4	1795.0	100.0	115.4	32.1	6570.9
1989	1137.4	3297.6	1610.0	98.9	103.5	28.8	6276.1
1990	1046.5	366.7	1769.4	91.0	91.0	25.3	3389.8
1991	1016.9	357.9	1432.8	88.4	76.1	21.3	2993.4
1992	1457.5	537.6	1209.8	126.7	60.5	20.2	3412.3
1993	1870.1	448.1	1138.3	94.0	70.5	24.8	3645.9
1994	1528.7	423.5	1240.6	76.8	57.6	19.2	3346.4
1995	1455.3	392.3	1476.4	78.3	47.0	15.7	3465.0
1996	1370.0	461.6	1737.3	91.3	48.4	16.1	3724.8

Notes:

a. Percentage contributions for dryland crops were obtained from Table C.6. Sunflowers were dropped because that crop had a weighting of zero percent.

b. Columns 1-6 contain products of the real producer price (Table C.5) and the respective weight to the total value of production (Table C.6). For example, the product of the real price and the percentage contribution to the total value of production for maize for 1996 was 1370.0, that is, (2978*0.46).

c. The national price series for dryland crops was created by a horizontal summation of the products of real producer price and percentage contributions to the total value of production.

Table C.8 Derivation of Household Dryland Agriculture and Gardens Price Series

Year	Detrended National Prices Series for Dryland Agriculture[a], Z$/kg	National Dryland Agriculture Price Index[b]	Derived Household Dryland Agriculture Price Series[c]	Deviation from Mean of Household Dryland Agriculture Price Index[d]	Deviation from Mean of Household Dryland Agriculture Price Adjusted for Relative Variability to Gardens[e]	Garden Price Index[f]	Derived Household Garden Price Series[g]
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
1987	3.50	0.94	5.17	0.02	0.06	1.06	5.16
1988	3.53	0.95	5.22	0.03	0.09	1.09	5.27
1989	3.24	0.87	4.78	-0.05	-0.15	0.85	4.14
1990	3.39	0.91	5.01	-0.01	-0.03	0.97	4.72
1991	2.99	0.80	4.42	-0.12	-0.34	0.66	3.20
1992	3.41	0.92	5.04	0.00	-0.01	0.99	4.80
1993	3.65	0.98	5.38	0.06	0.17	1.17	5.70
1994	3.35	0.90	4.94	-0.02	-0.06	0.94	4.55
1995	3.46	0.93	5.12	0.01	0.03	1.03	5.01
1996	3.72	1.00	5.50	0.08	0.24	1.24	6.00
Average	3.43	0.92	5.06			1.00	4.85
SD[g]	0.21	0.06	0.31			0.16	0.79
CV%[i]	6.05	6.05	6.05			16.34	16.34

Notes:

a. Detrending was done to eliminate the contribution of a time trend in the derived national price series for dryland agriculture (Table C.7, Column 7), thus allowing only normal year-to-year variability to remain.

b. The index was created by dividing Column 1 prices for each year by the base year (1996) price of Z$3.72/kg in Column 1.

c. The household price series for dryland agriculture was created by multiplying the value of the price index for each year (Column 2) by the base year aggregate household dryland price of Z$5.5/kg in Table B2 (Column 3).

d. Deviations of the national price index for dryland crops (Column 2) from the mean were derived by subtracting the mean value of the price index (0.92) from each observation of the price index in Column 2.

e. Garden prices used in this study were 2.7 times as variable as dryland agriculture prices in order to reflect relative variability obtained from expert opinion (Table 4.15). The values in Column 5 for each year were calculated using the formula: (PDEV*PRATING)/(PBASEOBS/PMEAN) where PDEV is the deviation from the mean of the price index for dryland agriculture (Column 4), PRATING is the value of the index of variability of garden values of output relative to that for dryland agriculture (i.e., 2.7), PBASEOBS is the base value of the price index for dryland agriculture in 1996 (i.e., 1.00 in Column 2), and PMEAN is the average value of the price index for dryland agriculture (i.e., 0.92 in Column 2).

f. The gardens price index was created by adding values in Column 5 for each year to the base year value of the national dryland crops price index of one (1.0) in Column 2.

g. The household garden price series was created using Column 6 values and the base year garden price of Z$6.00/kg (in Table B.2, Column 3). The household garden price for 1995 (p9) was derived as follows: p9 = p10*(i9/i10), where p10 is the base year garden price for 1996, and i9 and i10 are values of the price index for gardens in 1995 and 1996 respectively. Garden prices for the other years were derived in a similar way.

h. SD = Standard Deviation.

i. CV% = Coefficient of Variation as a percentage.

Table C.9 Values of Output[a] by Sector for Wealth Quartile 1 (Z$)

Sector	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Gardens	1517.3	1551.2	1220.6	1403.7	957.6	1365.3	1753.4	1457.2	1510.2	1827.8
Dryland	2132.6	8332.1	1955.4	7072.7	2098.9	148.0	7258.6	3228.8	2787.7	6019.4
Woodlands	1918.0	2219.3	1902.4	2163.7	1905.1	1816.4	2163.5	1969.9	1949.3	2103.9

Notes:

a. The calculations were based on price series presented in Table 4.19 and yields for wealth quartile 1 that are presented in Tables 4.16-4.18.

Table C.10 Coefficients of Variation For Values of Output[a] for Gardens and Woodlands Relative to Dryland Agriculture, Wealth Quartile 1 (Z$)

Sector	Standard Deviation	Average	CV%	CV% Gardens/ CV% Dryland Agriculture	CV% Woodlands/ CV% Dryland Agriculture
Dryland Agriculture	2808.4	4103.4	68.4		
Gardens	248.8	1456.4	17.1	0.25	
Woodlands	138.9	2011.2	6.9		0.10

Notes:

a. The calculations were based on price series presented in Table 4.19 and yields for wealth quartile 1 that are presented in Tables 4.16-4.18. Calculations were done after adjusting garden price variability.

Table C.11 Derivation of Household Woodlands Price Series

Year	National Dryland Crop Price Index[a]	Deviation from Mean of Household Dryland Agriculture Price Index[b]	Deviation from Mean of Dryland Agriculture Price Index Adjusted for Relative Variability to Woodlands[c]	Woodlands Price Index [d]	Derived Household Woodlands Price Series[e]
	Column 1	Column 2	Column 3	Column 4	Column 5
1987	0.94	0.02	0.00	1.00	0.25
1988	0.95	0.03	0.00	1.00	0.25
1989	0.87	-0.05	-0.01	0.99	0.25
1990	0.91	-0.01	0.00	1.00	0.25
1991	0.80	-0.12	-0.01	0.99	0.24
1992	0.92	0.00	0.00	1.00	0.25
1993	0.98	0.06	0.01	1.01	0.25
1994	0.90	-0.02	0.00	1.00	0.25
1995	0.93	0.01	0.00	1.00	0.25
1996	1.00	0.08	0.01	1.01	0.25
Average	0.92			1.00	0.25
SD[f]	0.06			0.01	0.00
CV%[g]	6.05			0.61	0.61

Notes:

a. The national price index for dryland crops was obtained from Table C.8, Column 2.

b. Deviations of the national price index for dryland crops from the mean of the national price index for dryland crops were obtained from Table C.8, Column 4.

c. Adjusted values of deviations in Column 3 for each year were calculated using the following formula: (PDEV*PRATING)/(PBASEOBS/PMEAN) where PDEV is the deviation from the mean of the price index for dryland agriculture (Column 2), PRATING is the value of the index of variability of woodlands values of output relative to that for dryland agriculture (i.e., 0.1 in Table 4.15), PBASEOBS is the base value of the price index for dryland agriculture in 1996 (i.e., 1.00 in Column 1), and PMEAN is the average value of the price index for dryland agriculture (i.e., 0.92 in Column 1).

d. The adjusted dryland crops price index was created by adding values in Column 3 for each year to the base year value of the national dryland crops price index (i.e., 1.00 in Column 1).

e. The woodlands base year price of Z$0.25 was obtained from Table B.2, Column 3. Household woodlands prices for states of nature 1-9 were derived using the following formula: p9 = p10*(i9/i10), where p10 is the aggregate household woodlands price in state of nature 10, and i9 and i10 are values of the price index for woodlands in states of nature 9 and 10 respectively. Woodlands prices for the other years were derived in a similar way.

f. SD = Standard Deviation.

g. CV% = Coefficient of Variation as a percentage.

APPENDIX D

Computation of Inter-Sector Expenditures

This appendix details the procedures that were used to calculate the value of inter-sector expenditures. Problems were encountered in the preliminary analysis pertaining to the difficulty in satisfying the household income constraint. This led to an investigation of the extent of inter-sector expenditures given that income into the household is used in different sectors. Results of the investigation showed that the domestic sector was the only subsidised sector. Values of subsidies to the domestic sector derived from dryland agriculture, gardens and woodlands sectors were calculated for each state of nature. Calculations for values of inter-sector transfers to the domestic sector in state of nature 10 are presented first, followed by those for transfers in states of nature 1-9.

D1 Computing Values of Domestic Sector Subsidies for State of Nature 10

The following sections describe how values of inter-sector expenditures to the domestic sector in state of nature 10 were calculated by wealth quartile for double sector (dryland agriculture and gardens) and tri-sector (dryland agriculture, gardens and woodlands) household models.

D1.1 Values of Domestic Sector Subsidies for State of Nature 10 for Double Sector Models

Average income and expenditure figures for each sector in each wealth quartile were calculated by dividing aggregate household income and expenditures by the number of households in the respective wealth quartile. The mean surplus or deficit for each sector by wealth quartile was obtained by computing the difference between the average income and expenditure figures (Table D.1, Columns 1-3). Results for all wealth quartiles suggested that the domestic sector was the only one that had a deficit. This implied that domestic sector expenditures were subsidized by income derived from other sectors. The domestic sector deficit of Z$2386.54 in Table D.1 (Column 3) for wealth quartile 1 was allocated to the net revenue generating sectors in proportion to their contribution to total surpluses. The amount of the domestic sector deficit for wealth quartile 1 that was funded by the combined dryland agriculture and garden sectors (Z$1093.83 in Table D.1, Column 5) was then calculated by multiplying the percentage contribution to total surplus (i.e., 45.83% in Table D.1, Column 3) for these two sectors by the value of the domestic sector deficit (i.e., Z$2386.54 in Table D.1, Column 3). This figure represented a cost item in the income for state of nature 10 (equation 3.3-6). The same procedures were used to calculate the subsidies to the domestic sector funded by dryland agriculture and gardens sectors for wealth quartiles 2-4 (Tables D.2-D.4).

D1.2 Values of Domestic Sector Subsidies for State of Nature 10 for Tri-sector Models

The analysis above was extended to derive the subsidy contributions of the combined dryland agriculture, gardens and woodlands sectors to the domestic sector in tri-sector models for each wealth quartile. Table D.5 (Columns 1 and 2) provides the aggregate household mean income and mean expenditure figures for the combined dryland agriculture, gardens and woodlands sectors that were used to calculate the size of their combined subsidy contribution to the domestic sector (Table D.5, Column 7). The size of the subsidy to the domestic sector was higher in the tri-sector models because the income base had increased by virtue of having an additional sector; that is, woodlands.

D2 Computing Values of Domestic Sector Subsidies for States of Nature 1-9

The following sections describe how values of inter-sector expenditures to the domestic sector for states of nature 1-9 were calculated by wealth quartile for double sector and tri-sector household models.

D2.1 Values of Domestic Sector Subsidies for States of Nature 1-9 for Double Sector Models

Having established the value of the transfer to the domestic sector for state of nature 10, the question remained regarding how to treat states of nature 1-9. Rather than estimate the models with a constant value of domestic sector expenditures funded by the other sectors modelled, it was deemed appropriate to create an index of transfers to the domestic sector that varied by state of nature. This was justified on the grounds that households likely adjust their domestic expenditures by state of nature. For example, households may consume less in drought years as a coping strategy.

In creating values of transfers to the domestic sector for states of nature 1-9, the value of production in each state of nature for dryland agriculture and gardens was obtained as the product of the respective prices, yields, and observed planted[59] acreage. Table D.6 and

59 Planted acreage was assumed to be constant for all 10 states of nature. The observed planted acreage for state of nature 10 was used. Yield and price series derived in Appendix C were used for this calculation.

Table D.7 give prices, yields, observed production data and values of production for dryland agriculture and garden sectors for wealth quartile 1. The total value of production for each state of nature for wealth quartile 1 was obtained as the sum of the values of production for dryland agriculture and gardens (Table D.8).

Next, an index for the total value of production for the double sector models for each wealth quartile was created by dividing the total value of production in each state of nature by the total value of production in state of nature 10 (i.e., base state). The parameter VINDEX in Table D.8 represents values of the index in each state of nature for the double sector models for wealth quartile 1. The indices of the total value of production reflect variability in total values of production in each state of nature relative to that for state of nature 10. Values of transfers to the domestic sector ($DOMEXP_k$) for wealth quartile 1 by state of nature in the double sector models in equation 3.3-6 were obtained by multiplying the value of the subsidy in state of nature 10 by the values of the index of the total value of production (VINDEX) in each state of nature (Table D.8). These procedures produced dollar values of transfers to the domestic sector that enter as cost items in income equation 3.3-6. Table 4.20 provides values of transfers to the domestic sector for double sector models in each state of nature by wealth quartile.

D2.2 Values of Domestic Sector Subsidies for States of Nature 1-9 for Tri-sector Models

The analysis above was extended to derive values of transfers to the domestic sector for states of nature 1-9 for the tri-sector models by wealth quartile. In the tri-sector models, the total value of production in each state of nature was obtained as the sum of values of production for dryland agriculture, gardens and woodlands by wealth quartile. Table D.9 provides values of production by state of nature for the woodlands sector for wealth quartile 1. Table D.10 provides values of the subsidy contributions by dryland agriculture, gardens and woodlands sectors to domestic expenditures for wealth quartile 1. These procedures produced dollar values of transfers to the domestic sector that enter as cost items in income equation 3.5-6. Table 4.21 provides values of domestic expenditures for the tri-sector models in each state of nature by wealth quartile.

Table D.1 **Gardens and Dryland Agriculture Subsidy to Domestic Sector (Z$): Wealth Quartile 1**

Sector	Mean Income[a]	Mean Expenditure[b]	Surplus (Deficit)[c]	Surplus as % of Total Surplus[d]	Gardens + Dryland Agriculture Sectors Subsidy to Domestic Sector[e]
	Column 1	Column 2	Column 3	Column 4	Column 5
Gardens	842.70	144.38	698.32	12.26	
Dryland Agriculture	2566.22	654.24	1911.97	33.57	
Livestock	468.05	246.89	221.16	3.88	
Woodlands	793.56	10.13	783.42	13.76	
Domestic	2759.10	5145.64	(2386.54)	0	
Remittances	2080.32	0	2080.32	36.53	
Total	9509.96	6201.29	5695.20	100	
Gardens and Dryland Agriculture	3408.92	798.62	2610.29	45.83	1093.83

Notes:

a. Mean income values in Column 1 for each sector were obtained by dividing the total income (in Z$), summed over all households in wealth quartile 1, by the total number of households in wealth quartile 1 (i.e., 49 households, Table 4.3). Domestic income represents income from small-scale industries and local odd jobs.

b. Mean expenditure values in Column 2 for each sector were obtained by dividing the total expenditure (in Z$), summed over all households in wealth quartile 1, by the total number of households in wealth quartile 1.

c. The value of the surplus (or deficit in parentheses) in Column 3 for each sector in wealth quartile 1 was obtained by subtracting the values of mean expenditure from the values of mean income. The deficit for the domestic sector in Column 3 was Z$2386.54. The total value of the surplus in Column 3 was Z$5695.20. The total value of the surplus was obtained by adding surplus values for all sectors (except the domestic sector which had a deficit).

d. The percentage of the surplus for each sector to the total surplus in Column 4 was obtained by dividing the surplus of each sector by the total surplus for all sectors combined.

e. The value of the transfer from dryland agriculture and gardens for wealth quartile 1 to the domestic sector in state of nature 10 was Z$1093.83 in Column 5. This value was calculated by multiplying the percentage contribution of dryland agriculture and gardens to the total surplus (i.e., 45.83% in Column 4) by the value of the domestic sector deficit (i.e., Z$2386.54 in Column 3).

Table D.2 Gardens and Dryland Agriculture Subsidy to Domestic Sector[a] (Z$): Wealth Quartile 2

Sector	Mean Income	Mean Expenditure	Surplus (Deficit)	Surplus as % of Total Surplus	Gardens + Dryland Agriculture Sectors Subsidy to Domestic Sector
	Column 1	Column 2	Column 3	Column 4	Column 5
Gardens	934.03	201.34	732.69	10.19	
Dryland Agriculture	3787.88	938.54	2849.34	39.61	
Livestock	542.88	216.90	325.98	4.53	
Woodlands	572.57	397.77	174.80	2.43	
Domestic	2572.86	6392.79	(3819.93)	0	
Remittances	3110.78	0	3110.78	43.24	
Total	11521	8147.34	7193.59	100	
Gardens and Dryland Agriculture	4721.912	1139.88	3582.03	49.79	1902.12

Notes:

a. See Table D.1 footnotes on how similar calculations were done to derive the value of the transfer from dryland agriculture and gardens to the domestic sector. The value of the transfer from dryland agriculture and gardens to the domestic sector in state of nature 10 for wealth quartile 2 was Z$1902.12 in Column 5.

Table D.3 Gardens and Dryland Agriculture Subsidy to Domestic Sector[a] (Z$): Wealth Quartile 3

Sector	Mean Income	Mean Expenditure	Surplus (Deficit)	Surplus as % of Total Surplus	Gardens + Dryland Agriculture Sectors Subsidy to Domestic Sector[a]
	Column 1	Column 2	Column 3	Column 4	Column 5
Gardens	1241.66	275.77	965.89	9.55	
Dryland Agriculture	5859.40	1450.29	4409.12	43.60	
Livestock	801.84	305.97	495.87	4.90	
Woodlands	742.85	62.50	680.34	6.73	
Domestic	3955.23	8173.46	(4218.23)	0	
Remittances	3562.38	0	3562.38	35.22	
Total	16163.36	10267.98	10113.60	100	
Gardens and Dryland	7101.06	1726.05	5375.01	53.15	2241.83

Notes:

a. See Table D.1 footnotes on how similar calculations were done to derive the value of the transfer from dryland agriculture and gardens to the domestic sector. The value of the transfer from dryland agriculture and gardens to the domestic sector in state of nature 10 for wealth quartile 3 was Z$2241.83 in Column 5.

Table D.4 Gardens and Dryland Agriculture Subsidy to Domestic Sector[a] (Z$): Wealth Quartile 4

Sector	Mean Income	Mean Expenditure	Surplus (Deficit)	Surplus as % of Total Surplus	Gardens + Dryland Agriculture Sectors Subsidy to Domestic Sector
	Column 1	Column 2	Column 3	Column 4	Column 5
Gardens	1267.75	584.58	683.17	3.51	
Dryland Agriculture	7761.53	2192.77	5568.76	28.65	
Livestock	2043.34	907.56	1135.78	5.84	
Woodlands	351.99	112.78	239.21	1.23	
Domestic	2721.97	15746.99	(13025.02)	0	
Remittances	11812.81	0	11812.81	60.77	
Total	25959.39	19544.68	19439.73	100	
Gardens and Dryland Agriculture	9029.28	2777.35	6251.93	32.16	4188.92

Notes:

a. See Table D.1 footnotes on how similar calculations were done to derive the value of the transfer from dryland agriculture and gardens to the domestic sector. The value of the transfer from dryland agriculture and gardens to the domestic sector in state of nature 10 for wealth quartile 4 was Z$4188.92 in Column 5.

Table D.5 Dryland Agriculture, Gardens and Woodlands Sectors Combined Subsidy to the Domestic Sector for all Wealth Quartiles (Z$)

Wealth Quartile	Mean Income[a]	Mean Expenditure[b]	Surplus[c]	Total Surplus[d]	Surplus as % of Total Surplus[e]	Domestic Sector Deficit[f]	Subsidy to Domestic Sector[g]
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Lowest 25%	4202.48	808.76	3393.72	5695.20	59.59	2386.54	1422.11
25-50%	5294.48	1537.65	3756.83	7193.59	52.22	3819.93	1994.95
50-75%	7843.90	1788.56	6055.35	10113.60	59.87	4218.23	2525.59
Top 25%	9381.27	2890.13	6491.14	19439.73	33.39	13025.02	4349.20

Notes:

a. Mean income values in Column 1 for dryland agriculture, gardens and woodlands sectors combined were obtained by dividing the total income (in Z$) for these three sectors, summed over all households in each wealth quartile, by the total number of households in each wealth quartile. Mean income values by wealth quartile were obtained from Tables D.1-D.4.

b. Mean expenditure values in Column 2 for dryland agriculture, gardens and woodlands sectors combined were obtained by dividing the total expenditure (in Z$) for these three sectors, summed over all households in each wealth quartile, by the total number of households in each wealth quartile. Mean expenditure values by wealth quartile were obtained from Tables D.1-D.4.

c. The value of the surplus for dryland agriculture, gardens and woodlands sectors in Column 3 for each wealth quartile was obtained by subtracting the values of mean expenditures from the values of mean income.

d. Total surplus values in Column 4 by wealth quartile were obtained from Column 3 of Tables D.1-D.4 respectively.

e. The percentage of the surplus for each sector to the total surplus in Column 5 was obtained by dividing the surplus of each sector by the total surplus for all sectors combined.

f. Values of domestic sector deficits in Column 6 for wealth quartiles 1-4 were obtained from Column 3 of Tables D.1-D.4 respectively. The domestic sector is the only sector that had a deficit.

g. The value of the transfer from dryland agriculture, gardens and woodlands sectors to the domestic sector in Column 7 was calculated by multiplying values of Column 5 and Column 6 for each wealth quartile.

Table D.6 Value of Dryland Agriculture Production for Wealth Quartile 1 by State of Nature (Z$)

	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Dryland Agriculture Price[a], Z$/kg	5.17	5.22	4.78	5.01	4.42	5.04	5.38	4.94	5.12	5.50
Dryland Agriculture Yield[a], kg/acre	151.84	588.38	150.65	520.58	174.95	10.82	496.75	240.74	200.74	403.21
Actual Production[b], acres	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
Value of Production[c], Z$	2132.58	8332.10	1955.38	7072.65	2098.94	147.98	7258.65	3228.84	2787.71	6019.38

Notes:

a. Prices and yields are not actual values but instead are values from the derived series. Dryland agriculture yields and prices were obtained from Table 4.16 and Table 4.19 respectively. The calculations for deriving yields and prices are presented in Appendix C.

b. Planted acres were considered to be constant for all states of nature in the models developed. They represent the observed planted dryland agriculture acreage for wealth quartile 1 in state of nature 10 based on survey data. Planted acres were obtained from Table 6.1.

c. The value of production (Z$) for dryland agriculture for each state of nature was obtained by multiplying the dryland agriculture price (Z$/kg) by yield (kg/acre) and acreage planted.

Table D.7 Value of Garden Production for Wealth Quartile 1 by State of Nature (Z$)

	State of Nature									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gardens Price [a], Z$/kg	5.16	5.27	4.14	4.72	3.20	4.80	5.70	4.55	5.01	6.00
Gardens Yield[a], kg/acre	602.02	602.5	603.29	608.65	611.91	581.38	629.56	654.87	617.22	623.24
Actual Production[b], acres	0.4888	0.4888	0.4888	0.4888	0.4888	0.4888	0.4888	0.4888	0.4888	0.4888
Value of Production [c], Z$	1517.34	1551.2	1220.63	1403.73	957.59	1365.26	1753.43	1457.16	1510.21	1827.84

Notes:

a. Prices and yields are not actual values but instead are values from the derived series. Gardens yields and prices were obtained from Table 4.17 and Table 4.19 respectively. The calculations for deriving yields and prices are presented in Appendix C.

b. Planted acres were considered to be constant for all states of nature in the models developed. They represent the observed planted gardens acreage for wealth quartile 1 in state of nature 10 based on survey data. Planted acres were obtained from Table 6.1.

c. The value of production (Z$) for gardens for each state of nature was obtained by multiplying the gardens price (Z$/kg) by yield (kg/acre) and acreage planted.

Table D.8 Domestic Sector Expenditures Funded by Dryland Agriculture and Garden Sectors in Double Sector Models for Wealth Quartile 1 by State of Nature (Z$)

	State of Nature									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dryland Agriculture Production[a], Z$	2132.58	8332.10	1955.38	7072.65	2098.94	147.98	7258.65	3228.84	2787.71	6019.38
Garden Production[a], Z$	1517.34	1551.20	1220.63	1403.73	957.59	1365.26	1753.43	1457.16	1510.21	1827.84
Total Value of Production[b], Z$	3649.92	9883.31	3176.01	8476.38	3056.53	1513.24	9012.08	4686.0	4297.93	7847.22
VINDEX[c]	0.47	1.26	0.40	1.08	0.39	0.19	1.15	0.60	0.55	1.0
DOMEXP[d], Z$	508.77	1377.64	442.71	1181.53	426.05	210.93	1256.2	653.19	599.09	1093.83

Notes:

a. Values of production (Z$) for dryland agriculture and gardens for each state of nature were obtained from Tables D.6 and Table D.7.

b. The total value of production ($) for the double sector model for each state of nature was obtained as a sum of values of production for dryland agriculture and gardens.

c. VINDEX is an index for the total value of production that was created by dividing the total value of production in each state of nature by the total value of production in state of nature 10 (i.e., base state).

d. The transfer from dryland agriculture and gardens sectors to the domestic sector (DOMEXP) in the double sector models was Z$1093.83 in state of nature 10 for wealth quartile 1. This figure was obtained from Table D.1, Column 5. Values of transfers to the domestic sector expenditures in states of nature 1-9 were obtained by multiplying the value of the index of the value of production (VINDEX)) in each state of nature by the value of the transfer to the domestic sector expenditures in state of nature 10.

Table D.9 Value of Woodlands Production for Wealth Quartile 1 by State of Nature (Z$)

	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Woodlands Price[a], Z$/kg	0.25	0.25	0.25	0.25	0.24	0.25	0.25	0.25	0.25	0.25
Woodlands Yield[a], kg/hour	7.80	9.02	7.80	8.83	7.86	7.41	8.76	8.05	7.94	8.50
Actual Production[b], hours	990.05	990.05	990.05	990.05	990.05	990.05	990.05	990.05	990.05	990.05
Value of Production[c], Z$	1918.03	2219.31	1902.37	2163.69	1905.11	1816.43	2163.47	1969.90	1949.34	2103.86

Notes:

a. Prices and yields are not actual values but instead are values from the derived series. Woodlands yields and prices were obtained from Table 4.18 and Table 4.19 respectively. The calculations for deriving yields and prices are presented in Appendix C.

b. Actual hours of production were considered to be constant for all states of nature in the models developed. They represent the observed woodlands hours of production for wealth quartile 1 in state of nature 10 based on survey data (Table 6.2).

c. The value of production (Z$) for woodlands for each state of nature was obtained by multiplying the woodlands price (Z$/kg) by yield (kg/hour) and time (hours) spent collecting woodlands.

Table D.10 Domestic Sector Expenditures Funded by Dryland Agriculture, Gardens and Woodlands Sectors in Tri-Sector Models for Wealth Quartile 1 by State of Nature (Z$)

	State of Nature									
	1	2	3	4	5	6	7	8	9	10
Dryland Agriculture Production, Z$	2132.58	8332.10	1955.38	7072.65	2098.94	147.98	7258.65	3228.84	2787.71	6019.38
Garden Production, Z$	1517.34	1551.20	1220.63	1403.73	957.59	1365.26	1753.43	1457.16	1510.21	1827.84
Woodlands Production, Z$	1918.03	2219.31	1902.37	2163.69	1905.11	1816.43	2163.47	1969.90	1949.34	2103.86
Total Value of Production, Z$	5567.96	12102.61	5078.39	10640.07	4961.64	3329.67	11175.55	6655.91	6247.26	9951.08
VINDEX[d]	0.56	1.22	0.51	1.07	0.50	0.33	1.12	0.67	0.63	1.00
DOMEXP[e], Z$	795.72	1729.59	725.75	1520.57	709.07	475.84	1597.10	951.20	892.80	1422.11

Notes:

a. Values of production for dryland agriculture and gardens in each state of nature were obtained from Tables D.6 and D.7 respectively.
b. Values of woodlands production in each state of nature were obtained from Table D.9.
c. The total value of production ($) for the tri-sector sector model in states of nature 1-10 was obtained as a sum of values of production for dryland agriculture, gardens and woodlands.
d. VINDEX is an index for the total value of production that was created by dividing the total value of production in each state of nature by the total value of production in state of nature 10 (i.e., base state).
e. The transfer from dryland agriculture, gardens and woodlands sectors to the domestic sector (DOMEXP) in the tri-sector models was Z$1422.11 in state of nature 10 for wealth quartile 1. This figure was obtained from Table D.5, Column 7. Values of the transfer to the domestic sector expenditures in states of nature 1-9 were obtained by multiplying the value of the index of the value of production (VINDEX) in each state of nature by the value of the transfer to the domestic sector in state of nature 10.