Abstract

This paper investigates crop portfolio choices by farmers as an instrument to reduce risk exposure in a rural environment characterized by imperfect or missing credit and insurance markets. Following Kurosaki and Fafchamps (2002), we set up a dynamic model of production and consumption under price and yield risk, from which structural estimates of technology, consumption and risk parameters are derived using longitudinal data from a sample of coffee producers in Southern Ethiopia. Estimates of the determinants of risk aversion suggest that land size, used as a proxy for wealth, and institutional features related to the land tenure system are relevant factors in decreasing risk aversion, allowing households to engage in riskier activities. Nonetheless, the low value of the predicted risk aversion coefficient may suggest two interpretations. First, the perennial nature of coffee and the related adjustment costs accompanying investment decisions may prevent farmers from readily adjusting their portfolio to changed market conditions. Second, the agronomic system widespread in Southern Ethiopia characterized by the joint cultivation of coffee, enset and to a lesser extent cereals, may prove effective in protecting farmers from adverse market and weather events. In particular, the role of enset, a poor but drought resistant staple crop, seems important in shielding farmers from the negative effects of highly volatile coffee and cereal prices.

Keywords: Risk; Household models; Structural estimation.
1 Introduction

Rural households in developing countries are exposed to a number of shocks arising from a risky environment, including extreme weather conditions, pests, crop diseases and illnesses, and variable market conditions. Farmers are typically ill-equipped to face such shocks, mostly covariant shocks that make risk sharing agreements only partially effective (Townsend, 1994; Udry, 1995), since formal credit and insurance markets are normally missing or incomplete. Therefore households, in response to such shocks, adopt a variety of strategies (Glewwe and Hall, 1998), ex-ante to shield themselves against the shocks or to mitigate ex-post the negative effects.

These latter strategies may include: a) use of savings or sales of physical assets to smooth consumption. Livestock, being a liquidable asset, can typically play this role of buffer stock, even though the empirical evidence is not conclusive because the concern of losing a productive asset may inhibit distress sales of livestock by families (Fafchamps et al., 1998; Zimmerman and Carter, 2003); b) inter-household transfers, including informal insurance agreements within the community and transfers received, on a more or less regular basis, from better-off relatives or household members, such as remittances; c) changes in consumption patterns, such as switching to cheaper food items; d) migration or displacement of family members to look for other jobs.

Ex-ante strategies can typically include: e) diversification of income sources, balancing on-farm and off-farm activities; f) choice of a diversified crop portfolio, growing crops displaying low correlated returns; g) use of less risky technologies, for instance avoiding to purchase fertilizers (Dercon and Christiaensen, 2007); h) own production of food crops to avoid price risk and guarantee stable food supply.

Now, under survival concerns and liquidity constraints optimal portfolio strategies can bifurcate with wealthier families opting for high return-risk activities, whilst poor ones may remain stuck in low return-risk portfolios (Rosenzweig and Wolpin, 1993; Dercon, 1998). Therefore, a likely outcome is that risk induced poverty traps may emerge (Zimmerman and Carter, 2003).

These strategies are usually only partially effective, leaving a residual consumption risk (Rosenzweig and Wolpin, 2003) and come at a cost in terms of foregone consumption and profit opportunities.

For these reasons, there is a growing interest by policy makers in assessing the feasibility and effectiveness of programs aimed at providing market based risk management instruments to farmers, particularly after the withdrawal of the state from the direct control of commodity markets and the end of price stabilization schemes, following the adoption of structural adjustment programs in many developing countries. A preliminary step for the successful implementation of such programs is the assessment of the underlying demand for additional income insurance.

Sarris (2002), in his study on the theory and application of commodity insurance under a fixed production structure, identifies three methodologies to assess the willingness to pay (WTP) of producers for price or income insurance:
a) direct questioning of farmers and related contingent valuation techniques; b) indirect methods, combing theory and information at household level to indirectly estimate appropriate risk premiums; c) revealed preference methods, where the WTP is inferred from the analysis of the observed production and saving-investment decisions of farmers. Under the assumption that households choices are coherent with their risk attitudes, this method allows to estimate the latent demand for insurance given that households have already adopted self insurance mechanisms. The drawback is the necessity to build a general enough model to capture the households relevant choices and the heavy data requirements, even though rich household surveys are more and more available. Works using this methodology include Gautam, Hazell and Alderman (1994), Fafchamps, Udry and Czukas (1998), Kurosaki and Fafchamps (2002).

Our work belongs to this strand of literature and the methodology closely follows the study by Kurosaki and Fafchamps (2002), where risk attitudes and consumption smoothing parameters are estimated using panel data from Pakistan Punjab. Specifically, our aim is to investigate the determinants of crop portfolio decisions by farmers in a rural developing economy, under price and yield risk, where markets for credit and insurance are either incomplete or missing, assessing how risk-coping strategies of farm households, heterogeneous in risk attitudes and assets holdings, affect the composition of their crops portfolio. Therefore, we set up a portfolio model of production choices from which structural estimates of technology, risk and consumption preference parameters are derived. The model is fit to longitudinal data from a sample of coffee producers in Southern Ethiopia. The results may help verify the existence of a latent demand for crop insurance and allow to simulate the effects on welfare of alternative policies affecting the realization of shocks.

The model developed by Kurosaki and Fafchamps (2002), in addition to providing a useful benchmark for our study, correctly addresses the non-separability between production and consumption decisions arising from the presence of uncertainty and risk aversion. The authors find that even in developing countries with fairly well developed credit and input markets, consumption preferences do affect production decisions. As argued by Sadoulet and de Janvry (1995), in case of market failures in the output or factor markets due to transactions costs, shallow local markets or risk, the decision price faced by the household is no longer the exogenous market price but an internal shadow price. In the case of risk, whenever a complete set of state contingent securities spanning all possible sources of risks does not exist, the expected output or factor price is discounted by a markup, negative and positive respectively, reflecting the degree of risk aversion. As a consequence, separability breaks down and the production and consumption problem are to be considered jointly in terms of modeling (see also Roe and Graham-Tomasi (1986) for an application to a dynamic model with yield uncertainty).

Our work, in addition to increasing the dimension of Fafchamps and Kurosaki's portfolio model, represents a new empirical application to a rural context with features that makes it interesting, namely: a) poorly developed credit and input markets; b) a densely populated area with severe land constraints and a land
tenure system where sales are formally prohibited; c) the cultivation of perennial crops, such as coffee, which implies the bearing of adjustment costs that may prevent producers from readily adjusting their crop portfolio to changing market conditions, further increasing the uncertainty of investment decisions and thus the importance of risk attitudes. Such features, in particular the role of the land tenure system, have been taken into account in the specification of the risk aversion determinants, as well as the potential heterogeneity in risk preferences arising from different assets holding.

The paper is organized as follows. In Section 2 the institutional framework of the area under study is described, while Section 3 presents the general theoretical model and how it is solved. An assessment of production and consumption risk is provided in Section 4, along with a description of households’ crop portfolio. The empirical specification and the estimation methodology are illustrated in Section 5, while Section 6 describes the data used and provides summary statistics. Finally, Section 7 presents the estimation results and Section 8 the final remarks and possible extensions of the present work.

2 Institutional framework

Ethiopia moved toward a market based economy only in the late 1980s. After the removal from power of the emperor by the revolution in 1974, the military government of Col. Mengistu Hailemariam established a communist-inspired strong control on the economy, with the nationalization of most large private companies and the imposition of price controls and trade restrictions, notably on agricultural production. Land became state-owned and were redistributed to rural households who kept the right to cultivate it for their own benefit.

Two major events occurred to the country during the 1980s, a wide-spread famine in 1984-85 and the civil war against the government forces, affecting mainly the Northern regions of Ethiopia, and leading eventually to the defeat of the Derg regime in 1991 by a coalition of rebel forces, the Ethiopian People’s Revolutionary Democratic Front (EPRDF), that restored security in most areas of the country.

Actually, since 1988 the economic crisis had led to some economic reforms toward a more liberalized economy, including the abolition of high rural taxes and trade restrictions on food crops. In 1992, further measures, including a large devaluation, were taken and these reforms became part of a wider structural adjustment program sponsored by the International Monetary Fund and the World Bank in 1994.

Despite a series of land tenure reforms during the 1990s, driven by strong population pressure and leading to the removal of many restrictions on rental and sharecropping, land remains state-owned and individuals are given only use rights. Although several studies (Fafchamps and Pender, 2001) have highlighted how the operation of land lease markets may guarantee an efficient use of variable inputs, land tenure insecurity and limited transfer rights may hinder long-term investments, such as planting or replanting of perennial crops (Dercon
et al, 2007).

These features of the Ethiopian land tenure system are particularly relevant to our study as the economy of the two villages under investigation, Adado and Aze Deboa, belongs to the so called enset-based agricultural system, characterized by the widespread cultivation of enset, a semi-permanent food crop, together with other crops such as coffee, a tree crop\(^1\).

3 Theoretical model

In this section we lay out the theoretical model and the main assumptions made. Some of them are justified by the specific characteristics of this rural economy and the focus on risk of the study, others respond mainly to the opportunity of keeping the model close to the empirical specification, which is partly driven by data availability. Therefore: a) labour market is not modeled, as off-farm employment is rare in the area and occurs mainly through labour sharing agreements. Thus, we are not distinguishing between family and hired labour, which is nonetheless employed at harvest time; b) labour, as other joint inputs, is assumed not allocatable to different crops, hence it is applied in somewhat constant proportions to cultivated land; c) land market is not considered, since as explained in the previous section, transactions are prohibited by law (yet land rental is active); d) credit and liquidity constraints are not included, even though in-kind working capital loans (fertilizers, pesticides) from cooperatives under government guarantees are available; e) saving or dissaving in the form of livestock purchases or sales, as well as in other forms, such as grain storage, is not modelled. While livestock transactions are by far less important in the villages under study than in pastoralist communities, this choice admittedly prevents us from modelling a possibly interesting asset dynamics.

We assume that household \(i\) maximizes welfare defined, over a finite time horizon \(T\), as the expected value of an intertemporally additive utility function \(u(.)\)

\[
V_{i,t} = E_{i,t} \sum_{\tau=0}^{T} \beta^{\tau} u(c_{i,t+\tau}, z_{i,t+\tau}^h).
\]

(1)

where \(c_{i,t}\) is a vector of \(R\) consumption goods, including staple crops, animal and other non-food products and \(z_{i,t}^h\) is a vector of household characteristics, such as the number of household members, the education of the household head and so forth. Households discount future utilities over time according to the constant discount factor \(\beta\). In order to simplify notation, in what follows the subscript \(i\) is dropped. We are thus moving within the expected utility framework, without dealing explicitly with downside risk (Kimball, 1990) and thus focusing in the statistical model on the first two moments of the stochastic processes governing

\[^1\text{More precisely, Adado can be classified as belonging to the enset sub-system where enset is the predominant staple food crop, typical of Sidama and Gurage ethnic groups, while in Aze Deboa it is a co-staple together with cereals and tuber crops, as it is common among Hadiya, Wolayita and other SNNPR groups.}\]
the random variables.

Since utility is additively separable, given total consumption expenditure and current consumption prices $p^c_t$, we can solve for $c_t$ to get the indirect utility function $v(c_t, p^c_t)$ with the usual properties.

Total household income $y_t$ is given by farm profits, either from cropping $y^a_t$ or livestock rearing $y^b_t$, as well as from other revenues $y^w_t$ assumed to be exogenous, such as wage from off-farm work, profits from self-employment and remittances

$$y_t = y^a_t + y^b_t + y^w_t. \quad (2)$$

Profits from livestock rearing are given by

$$y^b_t = p^b_t q^b_t - w^b_t x^b_t \quad (3)$$

where $q^b_t = F^b(B_t)$ is the quantity of livestock products, $B_t$ is the herding stock at the beginning of period $t$, expressed in tropical livestock units, $p^b_t$ and $w^b_t$ are vectors of output and input prices, respectively, and $x^b_t$ are the quantities of inputs used in livestock breeding.

Net revenues from crop cultivation are expressed as

$$\pi^a_t = \sum_{j=1}^{S} (p^j_t q^j_t - w^{j-1}_t x^{j-1}_t) \quad (4)$$

where

$$q^j_t = F^j(L^j_{t-1}, x^{j-1}_t; z^j_q, \epsilon_t) \quad j = 1, ..., S \quad (5)$$

is the production function for crop $j$, giving the maximum output attainable using land $L^j_{t-1}$ and other variable inputs $x^{j-1}_t$, conditional on farm specific characteristics $z^j_q$ and production shocks $\epsilon_t$, such as adverse weather conditions, pests and crop diseases; $p^j_t$ is the output price and $w^{j-1}_t$ a vector of input prices used in crop $j$ cultivation.

In the case of perennial crops, such as coffee, we have not included the tree stock in the production function, assuming that homogeneously planted land is a good proxy for it. As argued by Akiyama and Trivedi (1987), focusing solely on land allocation we are overlooking some of the features typical of perennial crops, namely: a) the existence of a biological gestation lag between planting and obtaining yield during which supply conditions may change; b) the bearing of adjustment costs related to the removal and planting of trees; c) the fact that the productivity of trees varies systematically with age; d) the heterogeneous nature of the tree stock, since age-yield profile and productive life depend on technical change and hence are not invariant with respect to the date (vintage) of the investment.

Land available to the household, $L_t$, is allocated between $S$ crops

$$\sum_{j=1}^{S} L^j_t = \bar{L}_t \quad \text{or} \quad \sum_{j=1}^{S} \theta^j_t = 1 \quad (6)$$
where $\theta^i_t$ is the share of cultivated land allocated to the $i$th crop. Since land is available in limited amount, increases in the share allocated to a crop occur mainly by substituting other cultivations.

We further add an agronomic constraint

$$g(\theta^1_t, ..., \theta^{S-1}_t) = 0$$

(7)

where $g(\cdot)$ describes the agronomic interactions between the $S-1$ free crops. It is non-increasing in the arguments and concave.

Time is divided into discrete intervals during which shocks occur and decisions are taken by households: 1) at the beginning of the crop year $t$ income from harvested crop production, cattle rearing and other activities is observed, as well as consumption prices; 2) total income $y_t$ is spent on consumption items $c^t_r$ or to purchase production inputs; 3) available land $L_t$ is allocated to $S$ competing crops, based on household consumption preferences, risk attitudes and expectations on future crop returns.

The decision problem faced by households is set in discrete time and can thus be written in Bellman equation form, comprising the following $S-1$ control variables $\theta^i_t$ and the state variables $y_t, p_t, \epsilon_t$

$$V_t(y_t, p_t, \epsilon_t) = \max_{\theta^i_t} \{ v(y_t, p_t) + \beta E_t V_{t+1}(y_{t+1}, p_{t+1}, \epsilon_{t+1}) \}$$

(8)

for $t < T$, subject to (7) and the non-negativity constraints $\theta^i_t \geq 0$.

Assuming that $v(\cdot)$ and $V(\cdot)$ are twice continuously differentiable and exploiting the Envelope Theorem, we can differentiate the Bellman equation with respect to the crop shares $\theta^i_t$ to get the Euler equations

$$\beta E_t \left[ \frac{\partial V_{t+1}}{\partial y_{t+1}} + \frac{\partial F^j}{\partial \theta^i_t} \right] + \mu_{jt} - \lambda_t \frac{\partial g}{\partial \theta^i_t} = 0 \ \forall j.$$  

(9)

As discussed in Kurosaki and Fafchamps (2002), the concavity of $V$ with respect to income or cash in hand depends not only on the curvature of $v$ with respect to consumption but also on the availability of assets to self-insure or risk sharing opportunities. If there are no security markets nor assets, $V_y$ tracks closely $v_y$, so that the curvature of $V$ simply reflects risk preferences. For poor households concerned about starvation the instantaneous utility $v$ is likely to be highly concave with respect to consumption, hence farmers are expected to take less risks. The availability of assets to buffer income shocks or other insurance opportunities instead allows to disentangle $V_y$ and $v_y$, reducing the curvature of $V$, which in the presence of complete insurance markets becomes linear and households behave as expected profit maximizers.

4 Risk assessment and crop portfolio

Rural households in developing countries are exposed to a variety of shocks, which may temporarily reduce their incomes or, in the worst cases, permanently affect their productive capacity. In this section we describe the main
features in terms of production and consumption risk of the surveyed villages and look at how they affect the choice of the crop portfolio by households.

As stressed by Fafchamps (1992), staple crops are usually cultivated by small farmers to achieve food self-sufficiency, as food markets are often thin and isolated, generating prices that are volatile and highly correlated with farmers’ own production patterns. On the other hand, cash crops provide a means to relax the household’s liquidity constraint because formal credit markets are often absent.

Keeping that in mind, on the basis of the relative importance in terms of allocated land and output and, in a portfolio strategy, looking also at the correlation of returns, we aggregate crops into four categories: 1) coffee ($\theta_1^t$), the main cash crop; 2) enset ($\theta_2^t$), a staple crop, usually not traded; 3) cereals ($\theta_3^t$), such as wheat or teff, often sold for cash; 4) other crops ($\theta_4^t$), including pulses, khat and other tree crops.

Figure 1 shows the pattern of monthly producer prices for selected crops in the SSNPR region between 1999 and 2004, the period spun by round 5 and 6 of the ERHS. The prices of coffee and khat, the most important cash crops in the region, are up to four times larger than those of teff, a noble cereal, and enset, but display a much higher volatility. A sharp fall in coffee price, from 8 birr/kg to about 3 birr/kg, is observable between the half of 2001 and the end of 2002, and only by the end of 2004 the price returns to its previous levels.

In order to assess the relative riskiness of crops and the implications of food price volatility on crop choices a normalized measure of volatility, such as the coefficient of variation, is useful. Moreover, although there is evidence that Ethiopian cereal markets are fairly well integrated (Dercon, 1995), high prices can be the consequence of poor harvests if markets are thin and isolated. This suggests looking at crop profits which convey information on both prices and yields.

Table 1 reports the mean coefficients of variation of annual net revenues per hectare for the four crop categories, obtained by averaging households’ coefficients computed over the period 1994-1999. The variability of net returns is high and roughly comparable between crops, though larger for cereals with respect to coffee, the main cash crop, due to higher yield risk. Growing cereals is by far more risky at Adado than Aze Deboa, but that holds in general also for the other crops.

Even though net revenues variability is high, the overall exposure to risk can be reduced if crop returns display low correlation. Table 2 shows the cross-sectional correlations of crop profits over the period 1994-1999. In general, the observed portfolio diversification seems more effective at Aze Deboa where, with the exception of round 5, net returns are weakly or even negatively correlated, as in the case of cereals. Conversely, positive and significant correlations are observed at Adado between coffee and enset, a likely result of intercropping, and between coffee and cereals, which could be explained by price co-movement and

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2 Producer prices with monthly frequency are provided at sub-regional level from 1996 to 2009 by the Central Statistics Agency (CSA) of Ethiopia.
the role of cereals as a cash crop. However, returns from enset show negative correlation with both cereals and other crops, confirming its role of safety staple in case of harvest failure of other crops.

Table 3 presents the coefficient of variation of consumer prices for five consumption categories, namely enset, cereals, livestock products, other food and non-food products. The categories have been identified by using observed households’ expenditure shares. With respect to net returns, consumer prices display a non-negligible but in general lower variability. A possible explanation is that the integration with regional food markets is sufficiently developed to mitigate the effects of crop failures on local prices.

Figure 1: Monthly producer prices for food and cash crops (SSNPR region)

Table 1: Coefficient of variation of net revenues (1994-1999)

<table>
<thead>
<tr>
<th></th>
<th>Coffee</th>
<th>Enset</th>
<th>Cereals</th>
<th>Other crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aze Deboa</td>
<td>0.71</td>
<td>0.84</td>
<td>0.95</td>
<td>1.20</td>
</tr>
<tr>
<td>Adado</td>
<td>1.10</td>
<td>1.20</td>
<td>1.50</td>
<td>1.40</td>
</tr>
<tr>
<td>Total</td>
<td>0.92</td>
<td>1.00</td>
<td>1.20</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Having described the main features in terms of production and price risk of the environment faced by households in the surveyed villages we now look at their response in terms of crop choices. Tables 4 and 5 show the mean shares of land allocated to different crops for land tenants engaged in crop production and included in the panel sample, 115 households at Adado and 70 at Aze Deboa, respectively.
Table 2: Correlations of crop profits (1994-1999)

<table>
<thead>
<tr>
<th></th>
<th>Aze Deboa</th>
<th>Adado</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coffee</td>
<td>Enset</td>
</tr>
<tr>
<td>Enset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.22</td>
<td>0.55*</td>
</tr>
<tr>
<td>3</td>
<td>0.10</td>
<td>0.62*</td>
</tr>
<tr>
<td>4</td>
<td>0.09</td>
<td>0.63*</td>
</tr>
<tr>
<td>5</td>
<td>0.16</td>
<td>0.31*</td>
</tr>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.20</td>
<td>0.24</td>
</tr>
<tr>
<td>3</td>
<td>-0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>-0.02</td>
<td>-0.07</td>
</tr>
<tr>
<td>5</td>
<td>0.37*</td>
<td>0.04</td>
</tr>
<tr>
<td>Other crops</td>
<td>-0.02</td>
<td>0.21</td>
</tr>
<tr>
<td>3</td>
<td>0.11</td>
<td>0.39*</td>
</tr>
<tr>
<td>4</td>
<td>0.07</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>0.49*</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

Table 3: Coefficient of variation of consumer prices (1994-1999)

<table>
<thead>
<tr>
<th></th>
<th>Enset</th>
<th>Cereals</th>
<th>Livestock prod.</th>
<th>Other food</th>
<th>Non food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aze Deboa</td>
<td>0.66</td>
<td>0.06</td>
<td>0.96</td>
<td>0.05</td>
<td>1.20</td>
</tr>
<tr>
<td>Adado</td>
<td>0.33</td>
<td>0.66</td>
<td>0.19</td>
<td>0.18</td>
<td>1.40</td>
</tr>
<tr>
<td>Total</td>
<td>0.50</td>
<td>0.36</td>
<td>0.58</td>
<td>0.35</td>
<td>1.30</td>
</tr>
</tbody>
</table>

In both villages landholdings are small, being on average below one hectare, which corresponds to the 75th percentile of the land distribution, even though average land size increases in 2004, particularly and even substantially at Adado. The crop portfolio is more diversified at Aze Deboa and oriented towards cereals (0.53 in 1999), even though the share of cereals decreases in 2004 (0.35) in favour of other crops (0.37). Adado is instead an area specialized in coffee production, intercropped with enset, whose shares, 0.45 and 0.47 respectively in 1999, remain stable over time. The proportion of land on average allocated to cereals is remarkably low in both rounds as many farmers do not grow cereals. However, as can be seen in Table 6 which shows the percentage of farmers not cultivating a certain crop, cereals are more cultivated in 2004, a likely consequence of the fact that cereals and other crops become relatively more profitable after the collapse of coffee prices in 2001 and 2002. The fact that the coffee share decreases at Aze Deboa, from 0.19 to 0.11, but not at Adado, is not surprising and can be explained by a different age composition of the tree stock. Given the opportunity cost of uprooting a still productive tree stock, the option value of waiting for a recovery of prices can be high and a better strategy may simply consist in skipping tree maintenance, such as pruning or the application of fertilizers and pesticides.

A research question which has drawn much attention in empirical work is whether small risk averse farmers are more likely to hold low risk-low return portfolios of activities, not enjoying the potential benefits of specialization in cash crop production or the adoption of risky but more profitable technologies.
The link between risk, wealth, risk attitudes and crop choices has been thoroughly investigated by Fafchamps (1992). He performs comparative statics analysis for a portfolio composed of a food and a cash crop and thus his results cannot be readily extended to a multi-crop portfolio. Yet, one important proposition states that if the covariance condition holds and income elasticity for the food crop is below unity, the relationship between farm size and cash crop for poor risk averse farmers is likely to be positive. Thus larger farmers should be more cash crop oriented than poor ones.

If we look at crop shares divided by land quartiles, and define farmers as small if they belong to the first three quartiles and large if belonging to the forth, strong conclusions cannot be drawn. The share of land allocated to enset, a typical staple crop, is indeed slightly larger for small farmers in both villages, but this is true also for coffee, an important cash crop. However, coffee is a long established cash crop in the region and, with respect to cereals, relatively less risky, as can be seen from the coefficient of variation of net returns. This consideration is particularly relevant if farmers are more concerned about crop losses than about the variability of net returns. Moreover, the share of cereals is higher for large farmers with respect to small farmers at Aze Deboa in 1999 (0.53 against 0.46) and Adado in 2004 (0.04 against 0.03), where noble cereals, such as teff, are used also as a cash crop.

<table>
<thead>
<tr>
<th>Table 4: Mean crop shares by land quartiles (1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartile</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td><strong>Aze Deboa</strong></td>
</tr>
<tr>
<td>I-III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td><strong>Adado</strong></td>
</tr>
<tr>
<td>I-III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

As it is typical of agricultural production, decisions are taken before uncertainty about future output and price is resolved and therefore the way expectations are formed must be considered. In what follows, we do not make specific assumptions on the stochastic processes of price and yields, focusing instead on the first two moments of the distribution of net revenues. Specifically, we assume that each year farmers form expectations on next year net revenues per hectare for each crop category, their variability and cross correlation by looking at past years realizations. Therefore, we are jointly considering price and yield risk.

3The condition is satisfied if the covariance between the price of one crop and the revenue of the other is smaller than the covariance between price and revenue of the same crop.
4We decided to group the first three land quartiles as they all include farmers with landholdings below one hectare and differences in crop choices may not be meaningful.
5The simple process of expectations formation assigns the same weight to past realizations,
### Table 5: Mean crop shares by land quartiles (2004)

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Coffee</th>
<th>Enset</th>
<th>Cereals</th>
<th>Other crops</th>
<th>Land (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aze Deboa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-III</td>
<td>0.12</td>
<td>0.13</td>
<td>0.36</td>
<td>0.35</td>
<td>0.60</td>
</tr>
<tr>
<td>IV</td>
<td>0.08</td>
<td>0.10</td>
<td>0.34</td>
<td>0.46</td>
<td>2.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.11</td>
<td>0.12</td>
<td>0.35</td>
<td>0.37</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Adado</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-III</td>
<td>0.44</td>
<td>0.43</td>
<td>0.03</td>
<td>0.09</td>
<td>0.66</td>
</tr>
<tr>
<td>IV</td>
<td>0.46</td>
<td>0.42</td>
<td>0.04</td>
<td>0.08</td>
<td>2.80</td>
</tr>
<tr>
<td>Total</td>
<td>0.45</td>
<td>0.43</td>
<td>0.03</td>
<td>0.08</td>
<td>1.20</td>
</tr>
</tbody>
</table>

### Table 6: Zero crop shares by land quartiles (%)

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th></th>
<th>2004</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-III</td>
<td>IV</td>
<td>Total</td>
<td>I-III</td>
</tr>
<tr>
<td><strong>Aze Deboa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>9.4</td>
<td>5.9</td>
<td>8.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Enset</td>
<td>3.8</td>
<td>0</td>
<td>2.9</td>
<td>3.7</td>
</tr>
<tr>
<td>Cereals</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.6</td>
</tr>
<tr>
<td>Other crops</td>
<td>28</td>
<td>29</td>
<td>29</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Adado</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>Enset</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cereals</td>
<td>93</td>
<td>96</td>
<td>94</td>
<td>84</td>
</tr>
<tr>
<td>Other crops</td>
<td>79</td>
<td>54</td>
<td>73</td>
<td>59</td>
</tr>
</tbody>
</table>

12
Using data on regional yields and prices from external sources and household survey data on farm specific factors affecting yields, Kurosaki and Fafchamps (2002) disentangle and separately model the covariant and idiosyncratic components of risk. This approach has the advantage of fully exploiting, in a rational expectations framework, the information set specific to each household in modelling expectations (Kurosaki, 1997).

Therefore, we use information on returns from round 1 through 4 to calculate moments up to the second order for the year 1999, updated using data from round 5 to construct expectations for the year 2004. As an example, Table 7 presents expectations computed using data from 1994 to 1997 for net returns and consumer prices by category. The latter are calculated as indexes by using unit values and household expenditure shares as weights from survey data.

Table 8 provides figures on the mean variances-covariances of farm profits computed over the period 1994-1997. Table 9 presents instead the mean covariances of profits with consumption prices calculated using the same period.

Table 7: Expectations on profits and consumption prices, 1994-1997

<table>
<thead>
<tr>
<th>Item</th>
<th>Aze Deboa</th>
<th>Adado</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td><strong>Profits (000 birr/ha)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>37.680</td>
<td>32.970</td>
</tr>
<tr>
<td>Enset</td>
<td>10.925</td>
<td>19.492</td>
</tr>
<tr>
<td>Cereals</td>
<td>6.831</td>
<td>7.650</td>
</tr>
<tr>
<td>Other trees</td>
<td>4.781</td>
<td>6.178</td>
</tr>
<tr>
<td>Other crops</td>
<td>5.423</td>
<td>5.981</td>
</tr>
<tr>
<td>Livestock prod.</td>
<td>3.816</td>
<td>10.927</td>
</tr>
<tr>
<td><strong>Consumption price indexes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>1.107</td>
<td>0.019</td>
</tr>
<tr>
<td>Enset</td>
<td>0.972</td>
<td>0.092</td>
</tr>
<tr>
<td>Livestock prod.</td>
<td>28.239</td>
<td>4.859</td>
</tr>
<tr>
<td>Other food prod.</td>
<td>8.149</td>
<td>0.460</td>
</tr>
<tr>
<td>Non-food prod.</td>
<td>32.585</td>
<td>21.745</td>
</tr>
</tbody>
</table>

which can be acceptable given the short period considered. Wherever farm specific data on net revenues are not available, average values computed for the respective land size category are used instead.
Table 8: Mean variances-covariances of farm profits, 1994-1997

<table>
<thead>
<tr>
<th></th>
<th>Coffee</th>
<th>Enset</th>
<th>Cereals</th>
<th>Livestock prod.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aze Deboa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>3035.618</td>
<td>152.767</td>
<td>-5.473</td>
<td>58.784</td>
</tr>
<tr>
<td></td>
<td>(13299.098)</td>
<td>(1016.053)</td>
<td>(145.856)</td>
<td>(324.698)</td>
</tr>
<tr>
<td></td>
<td>(507.222)</td>
<td>(84.6459)</td>
<td>(67.677)</td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>176.915</td>
<td>8.285</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(823.278)</td>
<td>(44.904)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock prod.</td>
<td></td>
<td></td>
<td></td>
<td>393.568</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(956.199)</td>
</tr>
<tr>
<td><strong>Adado</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>316538.413</td>
<td>23407.143</td>
<td>-912.822</td>
<td>20.996</td>
</tr>
<tr>
<td></td>
<td>(1163854.305)</td>
<td>(85219.801)</td>
<td>(39598.394)</td>
<td>(1638.1)</td>
</tr>
<tr>
<td>Enset</td>
<td>92333.932</td>
<td>4808.996</td>
<td>-96.496</td>
<td>-96.496</td>
</tr>
<tr>
<td></td>
<td>(352920.38)</td>
<td>(33933.81)</td>
<td>(808.934)</td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>4443.208</td>
<td>-46.02</td>
<td>-23.858</td>
<td>-5.526</td>
</tr>
<tr>
<td></td>
<td>(9986.192)</td>
<td>(220.228)</td>
<td>(145.245)</td>
<td>(15.735)</td>
</tr>
<tr>
<td>Livestock prod.</td>
<td>42.803</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(168.306)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The figures are given in 000 birr/ha. Standard deviations are reported in brackets.

Table 9: Mean covariances of profits and consumption prices, 1994-1997

<table>
<thead>
<tr>
<th></th>
<th>Cereals</th>
<th>Enset</th>
<th>Livestock prod.</th>
<th>Other food</th>
<th>Non food</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aze Deboa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>-0.641</td>
<td>3.974</td>
<td>197.798</td>
<td>-13.568</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(1.779)</td>
<td>(6.192)</td>
<td>(773.603)</td>
<td>(138.288)</td>
<td>(641.468)</td>
</tr>
<tr>
<td>Enset</td>
<td>-0.254</td>
<td>-4.455</td>
<td>128.866</td>
<td>-23.118</td>
<td>-15.191</td>
</tr>
<tr>
<td></td>
<td>(1.802)</td>
<td>(14.94)</td>
<td>(618.928)</td>
<td>(62.264)</td>
<td>(245.787)</td>
</tr>
<tr>
<td>Cereals</td>
<td>0.159</td>
<td>-0.457</td>
<td>-23.858</td>
<td>-5.526</td>
<td>-1.387</td>
</tr>
<tr>
<td></td>
<td>(0.692)</td>
<td>(1.885)</td>
<td>(145.245)</td>
<td>(15.735)</td>
<td>(281.966)</td>
</tr>
<tr>
<td><strong>Adado</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>166.588</td>
<td>18.394</td>
<td>5.714</td>
<td>57.758</td>
<td>1629.073</td>
</tr>
<tr>
<td></td>
<td>(677.033)</td>
<td>(64.061)</td>
<td>(25.739)</td>
<td>(248.987)</td>
<td>(21767.899)</td>
</tr>
<tr>
<td></td>
<td>(262.85)</td>
<td>(20.99)</td>
<td>(11.082)</td>
<td>(102.752)</td>
<td>(1565.178)</td>
</tr>
<tr>
<td>Cereals</td>
<td>-24.879</td>
<td>-1.733</td>
<td>-1.078</td>
<td>-9.908</td>
<td>46.382</td>
</tr>
<tr>
<td></td>
<td>(147.192)</td>
<td>(10.662)</td>
<td>(6.294)</td>
<td>(58.145)</td>
<td>(861.319)</td>
</tr>
</tbody>
</table>

Note: Standard deviations are reported in brackets.
5 Empirical specification

In this section we turn to the empirical specification of the model, assigning suitable functional forms and making further assumptions to ease the empirical tractability, in particular: a) variable inputs are attributed proportionally to the output value of different crops according to the \((M \times 1)\) coefficients vector \(\kappa_j\), where \(M\) is the number of inputs; b) only interior solutions for the control variables are considered; c) the residual crop category, negligible in terms of output value, is disregarded; d) as already discussed, price and yield are jointly modelled so that net returns per hectar \(\pi_j\) are used instead.

Net revenues from cropping can thus be expressed as

\[
y_{a}^{t+1} = \sum_{j=1}^{S} (p_{j}^{t+1} \xi_{j}^{t+1} - w_{j}^{t} \kappa_{j}) \theta_{j}^{t} L_{t} \tag{10}
\]

where \(\xi_{j}^{t+1}\) and \(\pi_{j}^{t+1}\) are random yields and random net returns per hectare of cultivated land, respectively.

The Bellman equation becomes

\[
V_{t}(y_{t}, p_{t}^{r}) = \max_{\theta_{t}} v(y_{t}, p_{t}^{r}) + \beta E_{t} V_{t+1}(\sum_{j=1}^{S} \pi_{j}^{t+1} \theta_{j}^{t} L_{t} + y_{b}^{t+1} + y_{w}^{t+1}) \tag{11}
\]

for \(t < T\), subject to (7) and the non-negativity constraints \(\theta_{j}^{t} \geq 0\).

Assuming interior solutions \((\mu_{jt} = 0)\) and differentiating with respect to the crop shares we get the first order conditions

\[
\beta E_{t} \left[ \frac{\partial V}{\partial y} \pi_{t+1}^{j} L_{t} \right] - \lambda_{t} \frac{\partial g_{t}}{\partial \theta_{j}^{t}} = 0 \quad \text{for } j = 1, ..., S - 1 \tag{12}
\]

and combining the above FOCs we have

\[
E_{t} \left[ V_{y} \left( \pi_{t+1}^{j} - \frac{g_{jt}}{g_{S-t}} \pi_{t+1}^{S} \right) \right] = 0 \quad \text{for } j = 1, ..., S - 2 \tag{13}
\]

where \(V_{y} \equiv \partial V/\partial y\) and \(g_{jt}\) denotes the partial derivative of \(g(.)\) with respect to \(\theta_{t}^{j}\).

We then perform a linearization that allows to solve the expectations and obtain first and second moments of the random variables. Thus, in spite of its local validity, we take a first order approximation of \(\partial V/\partial y\) around the expected values of income \(\bar{y}\) and prices \(\bar{p}\), as in Fafchamps (1992)

\[
V_{y} \approx \bar{V}_{y} + \sum_{r=1}^{R} \bar{V}_{ypr} (p^{r} - \bar{p}) + \bar{V}_{yy} (y - \bar{y}) \tag{14}
\]
where \( \bar{V}_y \) stands for \( V_y(\bar{y}, \bar{p}) \). After taking expectations and rearranging, equation (13) can be rewritten as

\[
\bar{V}_y \left[ E_t[\pi_{jt} - \frac{g_{jt}}{g_{S-1t}} E_t[\pi_{St}]] + \sum_{r=1}^{R} \frac{\bar{V}_y^{y'}}{V_y} E_t \left[ (p^r - \bar{p}^r) \left( \pi_{jt} - \frac{g_{jt}}{g_{S-1t}} \pi_{S-1t} \right) \right] \right] 
+ \bar{V}_y E_t \left[ (y - \bar{y}) \left( \pi_{jt} - \frac{g_{jt}}{g_{S-1t}} \pi_{S-1t} \right) \right] = 0 \quad \text{for } j = 1, \ldots, S - 1. \tag{15}
\]

As in Kurosaki and Fafchamps (2002), to make (15) empirically tractable we assign \( V \) the following power form

\[
V(y_t, p^r_t) = \frac{1}{1 - \Psi_t} \left[ y_t - \sum_{r=1}^{R} p^r_t \gamma^r \right]^{1 - \Psi_t} \tag{16}
\]

where \( \Psi_t \) is a relative risk aversion coefficient with respect to income after necessary consumption \( \sum_r p^r_t \gamma^r \) has been satisfied.

The standard Arrow-Pratt coefficient of relative risk aversion is obtained after adjusting for necessary consumption through the transformation

\[
R_t = \Psi_t \frac{E[y_t]}{E[y_t - \sum_r p^r_t \gamma^r]} \tag{17}
\]

We assume that the concavity of \( V \) depends on household’s ability to bear risk and thus we parameterize \( \Psi_t \) as

\[
\Psi_t = \psi_0 + \sum_h \psi_h z^h_t \quad h = 1, \ldots, H \tag{18}
\]

where \( z^h_t \) include household’s assets, such as land and livestock owned, demographic characteristics and proxies for human capital, such as the education of the household head, and institutional features like the land tenure system.

The price index in the indirect utility function is calculated as a geometric average, where \( \beta^r \) is the expenditure share of the \( r \)th good in the linear expenditure system

\[
p^r_t e^r_t = p^r_t \gamma^r + \beta^r (y_t - \sum_{r=1}^{R} p^r_t \gamma^r) \quad \text{for } r = 1, \ldots, R. \tag{19}
\]

Finally, as in Chavas and Holt (1996), a quadratic form is assigned to the technology constraint \( g(\theta^1_t, \ldots, \theta^{S-1}_t) \) to take into account agronomic constraints between the \( S - 1 \) free land shares, independent of past crop choices, such as crop complementarities and water requirements

\[
\theta^1_t - \alpha_0 - \sum_{j=1}^{S-2} [\alpha_{2j-1} \theta^{j+1}_t + \alpha_{2j} (\theta^{j+1}_t)^2] = 0. \tag{20}
\]
The structural model comprises the first order conditions for land allocation (15), the technology constraint (20) and the demand equations (19)

\[ E_t \left[ V_y \left( \pi_{jt} - \frac{g_{jt}}{g_{S-1t}} \right) \right] = \nu^t_j \quad \text{for } j = 1, \ldots, S - 2 \quad (21) \]

\[ \theta^t_i - \alpha_0 - \sum_{j=1}^{S-2} \left[ \alpha_{2j-1} \theta^{j+1}_i + \alpha_{2j} \theta^{j+1}_i \right] = \nu^t_i S^{-1} \quad (22) \]

\[ -p^r_t c^r + p^r_t \gamma^r + \beta^r (y_t - \sum_{r=1}^{R} p^r_t \gamma^r) = \nu^{r-1+r}_i \quad \text{for } r = 1, \ldots, R - 1. \quad (23) \]

Notice that one demand equation has been dropped because of the adding-up constraint.\(^6\)

The structural system is estimated by FIML. The disturbance vector \( \nu^t_i \) is assumed jointly normal, with variance-covariance matrix \( \Sigma \), hence the log-likelihood function for the system of \( p \) equations is given by

\[ \ln L(\Omega|\text{data}) = -\frac{pTN}{2} \ln(2\pi) - \frac{TN}{2} \ln |\Sigma| + \sum_{i=1}^{N} \sum_{t=1}^{T} \left( \ln |J_{i,t}| - \frac{1}{2} \nu^t_i \Sigma^{-1} \nu^t_i \right) \]  

(24)

where \( \Omega \equiv \{ \alpha, \beta, \gamma, \psi, \Sigma \} \) is the vector of parameters to be estimated, \( N \) is the number of households in the sample, \( T \) the time periods and \( J_{i,t} \) is the Jacobian transform matrix, since equations (21)-(23) do not yield a closed form solution in the crop shares \( \theta^t_i \).

6 Data description

The data used come from the Ethiopian Rural Household Survey (ERHS) conducted by the International Food Policy Research Institute (IFPRI), the Universities of Oxford and Addis Ababa. It is a longitudinal data set collected in 15 villages across the country over six rounds from 1989 to 2004 and provides a sample of 1477 households. It is not representative of all rural Ethiopia but covers all different agro-climatic areas. Our sub-sample comprises 185 households from two villages of the SSNP region in Southern Ethiopia, Adado and Aze Deboa, where coffee is produced. In particular, 70 households from Aze Deboa and 115 from Adado are followed in round 5 and 6, providing a balanced panel of 370 observations.

Table 10 describes the main characteristics of the survey area. The mean land size, computed over the two rounds, is below one hectare in both villages and, as already discussed, the share of land allocated to cereals is by far larger at Aze Deboa (0.41) than Adado, which is specialized in coffee production, intercropped with enset (0.45). The importance of cereals at Aze Deboa is reflected in the share of household food expenditure (0.30), while enset turns out to be

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\(^6\)The equation for other non-food products has been dropped because of the adding-up restriction arising from the use of expenditures instead of quantities consumed in the demand system.
an important staple in both villages. The proportion of livestock products in households' consumption is higher at Adado (0.19) than Aze Deboa (0.10), and that holds also for income derived from livestock rearing. This fact is a bit puzzling as the animal stock, measured in tropical livestock units, is four times larger at Aze Deboa than Adado. Though, a possible explanation could be given by the fact that livestock at Aze Deboa is composed by large size animals, such as cattle, used mainly in cereals production for plowing, rather than for food consumption. Income from cropping is higher at Aze Deboa than Adado, while the reverse is true for off-farm income, which is however negligible in both villages. Food consumption per month is higher at Aze Deboa, where the number of household members, as well as the share of adults on total household size, is larger than Adado, yielding a lower dependency ratio (0.35).

Table 10: Descriptive statistics (1999, 2004)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aze Deboa</th>
<th></th>
<th>Adado</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td><strong>Demographics and assets</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household size</td>
<td>7.76</td>
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<td>6.38</td>
<td>2.68</td>
</tr>
<tr>
<td>Dependency ratio</td>
<td>0.35</td>
<td>0.20</td>
<td>0.45</td>
<td>0.23</td>
</tr>
<tr>
<td>Livestock (tlu)</td>
<td>2.01</td>
<td>1.29</td>
<td>0.48</td>
<td>0.80</td>
</tr>
<tr>
<td>Land size (ha)</td>
<td>0.89</td>
<td>0.77</td>
<td>0.74</td>
<td>1.60</td>
</tr>
<tr>
<td><strong>Land allocation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee share</td>
<td>0.15</td>
<td>0.12</td>
<td>0.45</td>
<td>0.14</td>
</tr>
<tr>
<td>Enset share</td>
<td>0.14</td>
<td>0.09</td>
<td>0.45</td>
<td>0.16</td>
</tr>
<tr>
<td>Cereals share</td>
<td>0.41</td>
<td>0.20</td>
<td>0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>Other crops share</td>
<td>0.28</td>
<td>0.22</td>
<td>0.07</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Income sources - Consumption</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock income (birr)</td>
<td>119</td>
<td>183</td>
<td>160</td>
<td>203</td>
</tr>
<tr>
<td>Crop income (birr)</td>
<td>1628</td>
<td>2654</td>
<td>1193</td>
<td>1002</td>
</tr>
<tr>
<td>Wage and other income (birr)</td>
<td>234</td>
<td>970</td>
<td>284</td>
<td>1110</td>
</tr>
<tr>
<td>Food consumption (birr)</td>
<td>76</td>
<td>110</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td><strong>Expenditure shares</strong></td>
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<td></td>
</tr>
<tr>
<td>Cereals share</td>
<td>0.30</td>
<td>0.21</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Enset share</td>
<td>0.19</td>
<td>0.18</td>
<td>0.22</td>
<td>0.23</td>
</tr>
<tr>
<td>Livestock products share</td>
<td>0.10</td>
<td>0.15</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>Other food share</td>
<td>0.41</td>
<td>0.24</td>
<td>0.45</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>No. of observations</strong></td>
<td>140</td>
<td></td>
<td>230</td>
<td></td>
</tr>
</tbody>
</table>
7 Estimation results

We now turn to the estimation of the structural parameters of the system given by equations (21)-(23). The estimation is conducted using a balanced panel of $N = 185$ households (70 from Aze Deboa, 115 from Adado) over $T = 2$ years (1999 and 2004), for a total of 370 observations.

Table 11: Estimates of structural parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coeff.</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk aversion determinants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept ($\psi_0$)</td>
<td>0.192</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Land size ($\psi_1$)</td>
<td>-0.088</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Livestock owned ($\psi_2$)</td>
<td>0.154</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Education ($\psi_3$)</td>
<td>0.244</td>
<td>(0.039)</td>
</tr>
<tr>
<td>Market participation ($\psi_4$)</td>
<td>-0.109</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Property rights ($\psi_5$)</td>
<td>-0.139</td>
<td>(0.042)</td>
</tr>
<tr>
<td><strong>Consumption preferences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals share ($\beta_1$)</td>
<td>0.181</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Enset share ($\beta_2$)</td>
<td>0.095</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Animal products share ($\beta_3$)</td>
<td>0.144</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Other food share ($\beta_4$)</td>
<td>0.436</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Non food share ($\beta_5$)</td>
<td>0.127</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Cereals subsistence con. ($\gamma_1$)</td>
<td>0.222</td>
<td>(0.131)</td>
</tr>
<tr>
<td>Enset subsistence con. ($\gamma_2$)</td>
<td>3.174</td>
<td>(0.436)</td>
</tr>
<tr>
<td>Animal prod. subsistence con. ($\gamma_3$)</td>
<td>0.002</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Other food subsistence con. ($\gamma_4$)</td>
<td>-0.112</td>
<td>(0.082)</td>
</tr>
<tr>
<td>Non food subsistence con. ($\gamma_5$)</td>
<td>0.150</td>
<td>(0.005)</td>
</tr>
<tr>
<td><strong>Agronomic constraints</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept ($\alpha_0$)</td>
<td>0.236</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Linear term enset ($\alpha_1$)</td>
<td>1.134</td>
<td>(0.105)</td>
</tr>
<tr>
<td>Quadratic term enset ($\alpha_2$)</td>
<td>-1.603</td>
<td>(0.118)</td>
</tr>
<tr>
<td>Linear term cereals ($\alpha_3$)</td>
<td>-0.038</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Quadratic term cereals ($\alpha_4$)</td>
<td>-0.338</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Mean log-likelihood</td>
<td>-22.150</td>
<td></td>
</tr>
</tbody>
</table>

Since we are considering a four crops portfolio ($S = 4$) and five consumption categories ($R = 5$), the system comprises two first order conditions, one agronomic constraint and four demand equations (because of the adding-up constraint) for a total of seven ($p = 7$) equations.

Table 11 reports the estimates of the structural parameters, together with standard errors calculated by inverting the computed Hessian. Parameters are estimated with precision, as long as the assumptions and restrictions imposed by functional forms are acceptable.

As concerns consumption parameters, we observe that committed consumption is relatively high for enset, as expected being a staple crop, lower for cereals which are often used as a cash crop, while animal products and other food turn out to be inessential goods, as implied by the negative sign. Once satisfied
subsistence consumption, households reveal high preferences for cereals, animal products and other richer food products in the residual food category.

Table 12: LES - Price elasticities

<table>
<thead>
<tr>
<th>Cons./Price</th>
<th>Cereals</th>
<th>Enset</th>
<th>Animal prod.</th>
<th>Other food</th>
<th>Non food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>-0.867</td>
<td>-0.155</td>
<td>-0.002</td>
<td>0.042</td>
<td>-0.216</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.030)</td>
<td>(0.018)</td>
<td>(0.027)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Enset</td>
<td>-0.012</td>
<td>-0.402</td>
<td>-0.001</td>
<td>0.017</td>
<td>-0.087</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.065)</td>
<td>(0.007)</td>
<td>(0.012)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Animal prod.</td>
<td>-0.034</td>
<td>-0.183</td>
<td>-0.986</td>
<td>0.049</td>
<td>-0.253</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.038)</td>
<td>(0.123)</td>
<td>(0.035)</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Other food</td>
<td>-0.040</td>
<td>-0.209</td>
<td>-0.003</td>
<td>-1.072</td>
<td>-0.290</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.040)</td>
<td>(0.024)</td>
<td>(0.055)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Non food</td>
<td>-0.013</td>
<td>-0.066</td>
<td>-0.001</td>
<td>0.018</td>
<td>-0.451</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.010)</td>
<td>(0.008)</td>
<td>(0.013)</td>
<td>(0.022)</td>
</tr>
</tbody>
</table>

*Notes: Standard errors in parentheses*

Table 13: LES - Total expenditure elasticities

<table>
<thead>
<tr>
<th>Item</th>
<th>Coeff.</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>1.199</td>
<td>(0.141)</td>
</tr>
<tr>
<td>Enset</td>
<td>0.485</td>
<td>(0.084)</td>
</tr>
<tr>
<td>Animal prod.</td>
<td>1.408</td>
<td>(0.186)</td>
</tr>
<tr>
<td>Other food</td>
<td>1.614</td>
<td>(0.136)</td>
</tr>
<tr>
<td>Non food</td>
<td>0.513</td>
<td>(0.025)</td>
</tr>
</tbody>
</table>

Turning to price elasticities (Table 12), we see that own price elasticities are significant and have the expected signs; demand for animal products and other food is elastic, while that for staple crops, in particular enset, is quite inelastic, as expected. Nevertheless, the elasticity value close to one for cereals and the negative cross price elasticities seem to reveal that the staple crops are not real substitutes in consumption; rather, since we cannot rely on a simple price comovement explanation, cereals seem to play a double role as a food and cash crop, with consumption levels being reduced in favour of a higher marketed surplus to get advantage of periods characterized by high staple crops prices. In general, the importance of staple crops in households’ budgets is reflected in the negative cross price elasticities with other consumption items and the same holds for non-food expenditure. Conversely, cereals, enset and other food may substitute for animal products, even though elasticities are not significant.

As shown in Table 13, income elasticity is quite high for cereals, an ap-
preciated food crop, quite low for enset, an inferior staple crop, and high for other food and animal products. As to technology parameters, the high and significant value of the quadratic term for enset ($\alpha_2$) indicates the importance of technical considerations of joint production with coffee, as expected because of intercropping, even though the negative sign is puzzling. The mild concave relationship between coffee and cereals suggests that economic factors are more important than agronomic constraints.

As regards the determinants of risk aversion, the coefficients are all significant and display plausible signs. Land size, used as a proxy for wealth, has negative sign, as suggested by theory, while the ownership of livestock seems to increase risk aversion. In general, the availability of liquidable assets, buffering against downside risks, is traditionally seen as reducing risk aversion, even though a tentative reverse causality explanation might be given, where higher risk aversion leads households to accumulate precautionary saving in the form of liquidable assets. A higher education of the household’s head tends unexpectedly to increase risk aversion, while an increase in the proportion of production sold on the market reduces it. The same effect holds for the dummy reflecting perceived property rights on own cultivated land. This result confirms the conclusions of Gautam et al. (2007) who, using Ethiopian data, argue that tenure insecurity discourages long-term, potentially profitable but risky, investments, such as those in perennial crops.

Table 14: Summary statistics of risk parameters (1999, 2004)

<table>
<thead>
<tr>
<th>Risk aversion parameter, $\Psi_{i,t}$</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aze Deboa</td>
<td>0.464</td>
<td>0.234</td>
<td>-0.070</td>
<td>1.625</td>
</tr>
<tr>
<td>Adado</td>
<td>0.131</td>
<td>0.267</td>
<td>-1.500</td>
<td>1.005</td>
</tr>
<tr>
<td>Total</td>
<td>0.257</td>
<td>0.302</td>
<td>-1.500</td>
<td>1.625</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arrow-Pratt coefficient</th>
<th>Aze Deboa</th>
<th>Adado</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-III</td>
<td>0.941</td>
<td>2.930</td>
</tr>
<tr>
<td>IV</td>
<td>-0.687</td>
<td>2.930</td>
</tr>
<tr>
<td>Total</td>
<td>-0.151</td>
<td>11.444</td>
</tr>
</tbody>
</table>

Table 15: Risk aversion coefficients by land size

<table>
<thead>
<tr>
<th>Quantile</th>
<th>Aze Deboa</th>
<th>Adado</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-III</td>
<td>0.475</td>
<td>0.163</td>
</tr>
<tr>
<td>IV</td>
<td>0.437</td>
<td>0.037</td>
</tr>
<tr>
<td>Total</td>
<td>0.464</td>
<td>0.131</td>
</tr>
</tbody>
</table>
Table 14 presents summary statistics for the predicted values of the risk aversion parameter and derived coefficients. The risk parameter ranges between -1.50 and 1.62 and has an overall mean of 0.26. The mean value of $\Psi_{t,t}$ is lower at Adado (0.131), an area specialized in coffee production, a profitable but risky crop, than at Aze Deboa (0.464), where farming is more mixed. Comparing these values with estimates reported in other studies, the magnitude of the risk parameter is lower than in Kurosaki and Fafchamps (2002), 1.830, and also smaller than the value reported in Rosenzweig and Wolpin (1993), 0.96, for Indian farmers. The estimate for Aze Deboa is rather close to the predicted coefficient, 0.536, obtained by Harrison et al. (2010) from the expected utility model with no covariates in a field experiment conducted in India, Ethiopia and Uganda. The negative sign of the mean Arrow-Pratt coefficient of relative risk aversion $R_t$, -0.15, obtained from equation (17) after eliminating observations having negative or zero expected income after meeting subsistence requirements, is a consequence of large negative values for households whose income is close to subsistence consumption and with negative risk parameter. This result deserves further investigation.

The predicted values for the risk aversion parameter computed at mean values of the explanatory variables by land quartiles (Table 15) reflect the negative sign of the coefficient $\psi_1$ and thus decrease in both villages, but considerably at Adado, with the amount of land owned.

8 Concluding remarks

In this work we investigated crop portfolio choices as a strategy to reduce risk exposure in a rural environment characterized by imperfect or missing markets. The literature on the farm household (Roe and Graham-Tomasi 1986, Sadoulet and de Janvry 1995) demonstrated that in the absence of markets to copying with risk, separability between production and consumption decisions breaks down, so that the two economic decisions should be modelled jointly. Therefore, following Kurosaki and Fafchamps (2002), we set up a dynamic model of production and consumption under risk, from which structural estimates of technology, consumption and risk parameters are derived using longitudinal data from rural Ethiopia.

Empirical evidence shows that farmers’ portfolio is diversified and, to a more or lesser extent, both food and cash crops are cultivated. Estimates of the determinants of risk aversion suggest that land size, used as a proxy for wealth, and institutional features related to the land tenure system are relevant factors in decreasing risk aversion, allowing households to engage in riskier activities.

This is reflected in the predicted risk aversion parameters, computed by land quartiles, which decrease with the size of landholdings. Nonetheless, the value of the coefficients is low compared to other studies, suggesting two possible interpretations. First, the perennial nature of coffee and the related adjustment costs accompanying investment and disinvestment decisions, may prevent farmers from readily adjusting their portfolio to changed market conditions. Second,
the agronomic system widespread in Southern Ethiopia and characterized by the joint cultivation of coffee, enset and to a lesser extent cereals, may prove effective in protecting farmers from adverse market and weather events. In particular, the role of enset, a poor but drought resistant staple crop, seems important in shielding farmers from the negative effects of highly volatile coffee and cereal prices.

As to possible extensions of the present work, it would seem interesting to allow for choices concerning the investment in livestock also in the empirical specification, thus endogenizing the role of liquidable assets as an instrument for consumption smoothing or for accumulating precautionary saving. Another possibility would be to explicitly consider investments in production capacity in the form of replantings of existing stocks. Finally, the use of estimation methods such as maximum simulated likelihood might also allow to deal with corner solutions.
Appendices

A Derivation of estimable first order conditions

In order to obtain an estimable form for the approximated first order conditions (15), a parameterized version is required. Therefore, using (16), we first calculate \( \bar{V}_y, \bar{V}_{yy} \) and \( \bar{V}_{yp} \), evaluated at the expected values for prices, profits and incomes. Then, upon substituting such expressions into the first order conditions we obtain two second-order polynomial equations, \( FOC_{21} \) and \( FOC_{31} \), in the endogenous variables \( \theta \). The first condition \( FOC_{21} \) is for instance given by

\[
FOC_{21} \approx F_2 - F_1 (\alpha_1 + 2\alpha_2\theta^2) + \sum_{j=1}^{3} \left[ G_{j,2} - G_{j,1} (\alpha_1 + 2\alpha_2\theta^2) \right] \theta^j
\]

where the terms \( F \) and \( G \) are functions of constructed variables, \( Z \) and \( W \), and of the structural parameters \( \beta, \gamma \) and \( \Psi \) to be estimated. The subscripts \( j, a = 1, 2, 3 \) denote respectively coffee, enset and cereals, while \( r = 1, 2, 3, 4, 5 \) identify the consumption categories.\(^7\) The variable \( F_a \) is constructed as

\[
F_a = (1 - \Psi) \sum_{j=1}^{S} \gamma^j E \pi_j \sum_{r=1}^{R} \beta^r Z_{a,r}^1 + \Psi \sum_{r=1}^{R} \gamma^r Z_{a,r}^2
\]

\[
- (1 - \Psi) \sum_{r=1}^{R} \beta^r Z_{a,r}^3 + \sum_{r=1}^{R} \gamma^r Z_{a,r}^4 + \Psi Z_{a}^5 + Z_{a}^6
\]

while the variable \( G_{j,a} \) is given by

\[
G_{j,a} = (1 - \Psi) \sum_{r=1}^{R} \beta^r W_{j,a,r}^1 + \Psi W_{j,a}^2 + W_{j,a}^3,
\]

The variables \( Z \) and \( W \) are combinations of first and second moments of prices and profits and are defined as follows:

\[
Z_{a,r}^1 = \frac{\text{Cov}(\pi_a, p^r)}{E \pi_1}, \quad Z_{a,r}^2 = \frac{E \pi_r}{E \pi_1} Z_{a,r}^1, \quad Z_{a,r}^3 = (AE \pi_m + R)Z_{a,r}^1,
\]

where

\[
Z_{a,r}^4 = \frac{E \pi_a E \pi_r}{E \pi_1}, \quad Z_{a}^5 = \frac{A \text{Cov}(\pi_a, \pi_m)}{E \pi_1}, \quad Z_{a}^6 = \frac{E \pi_a Z_{a,r}^3}{E \pi_1 Z_{a,r}^1},
\]

\[
W_{j,a,r}^1 = LE \pi_j Z_{a,r}^1, \quad W_{j,a}^2 = \frac{A \text{Cov}(\pi_j, \pi_a)}{E \pi_1}, \quad W_{j,a}^3 = \frac{E \pi_j E \pi_a}{E \pi_1}.
\]

\(^7\)The subscripts for household, \( i \), and time, \( t \), have been dropped.
References


