Three essays on productivity and risk, marketing decisions, and changes in well-being over time

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ABSTRACT

This dissertation is composed of three essays; the first two examine the decision-making of potato producing households in Bolivia and the third examines well-being changes among Zimbabwe households. The first essay entitled "The role of risk mitigation in production efficiency: A case study of potato cultivation in the Bolivian Andes" estimates the costs of self-managing environmental risk through activity and environmental diversification. Risk management has the potential to reduce income variability but at the cost of increasing production inefficiency, which we measure employing a stochastic production frontier. Among variables capturing environmental diversification, discontinuity between fields has the most detrimental effect on production efficiency. Activity diversification, measured by the ratio of potato to total crop revenue, has a stronger impact on inefficiency and yield losses than any of the environmental diversification variables.

The second essay entitled "Determinants of market participation decisions and marketing choices in Bolivia" examines three decisions related to potato market participation: market entry, volume sold, and market choice. The first two are analyzed using a Heckman selection model. Results indicate that isolation, measured by population density and distance to markets, negatively impacts market entry. The most important determinant of quantity sold is land holding. Market choices are judged according to second-order stochastic dominance (SOSD). Market choices meeting the SOSD criterion

are referred to as optimal marketing strategies as they have the higher expected payoff for a minimal income variance. Results suggest that the probability of selecting an optimal marketing strategy increases with quantity sold, access to market information, and access to liquidity while it decreases with distance to markets.

The third essay entitled “A profile of changes in well-being in Zimbabwe, 2001-2007/8, using an asset index methodology” shows that it is possible to examine inter-temporal and spatial changes in well-being in the absence of consumption expenditures data by using an asset index. The asset index was constructed using Polychoric Principal Component Analysis. Results indicate that poverty and extremely poverty grew significantly in rural Zimbabwe while in urban areas, poverty diminished and extreme poverty grew.

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Three essays on productivity and risk, marketing decisions, and changes in well-being over time

Introduction

This dissertation is composed of three essays examining household decision-making and well-being in two developing countries, Bolivia and Zimbabwe. The first essay examines the costs of self-managing environmental risk in potato cultivation in the Bolivian Andes. The second essay analyzes market participation decisions and market choices of Bolivian potato producers with the objective of providing avenues to poverty alleviation through improved access to better markets. The third essay focuses on changes in well-being among Zimbabwean households between 2001 and 2007/8 as the country is going through a severe economic crisis.

The first two essays use a dataset obtained from a random household survey conducted in the Tiraque province, Cochabamba department, of Bolivia. This initiative was undertaken as part of the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP). The dataset is extensive and contains information on household demographics, agricultural production, commercialization of agricultural products, revenues, expenses, and others. More uniquely, this dataset includes the geographical coordinates of households and potato plots. This allows us to create powerful explanatory variables and control for the spatial environment in which the households are located during the econometric estimations.

The third essay uses the Income, Consumption and Expenditure Surveys (ICES) collected by the Central Statistical Office (CSO) of Zimbabwe in 2001 and 2007/8. These surveys are nationally representative and the latter was collected during a period of hyperinflation and economic crisis. This allows us to analyze how the country economic turmoil has affected its population well-being and inform Zimbabwean policy-markers about the situation faced by the poor.

The first essay entitled "The role of risk mitigation in production efficiency: A case study of potato cultivation in the Bolivian Andes" contributes to the literature by employing an intuitive approach to quantify the costs of environmental risk mitigation. Risk mitigation reflects a household strategy to reduce income variability and more precisely, production variability. Environmental and activity diversification are examples of risk mitigation. The first technique consists of cultivating the same crop in different micro-climatic regions, where environmental shocks are not perfectly correlated between regions. Activity diversification refers to cultivating, in the same micro-environment, crops that respond differently to weather shocks, such as cultivating a crop that goes well in humid conditions with a crop that does best in a dry environment. However, when production decisions are made to mitigate risk as opposed to maximize profit, production inefficiency and yield losses can arise. For this reason, we employ a stochastic production frontier to estimate the costs of risk mitigation in potato production by modeling the inefficiency component of the model as a function of environmental and activity diversification outcomes. This innovative approach allows to quantity the costs of the self-insurance techniques in the form of efficiency losses and yield forgone.

Households and potato plot geographical coordinates are crucial to create measure of environmental diversification such as travel-path distance between a field and the household, measure of effective distance between fields, and field clustering. In addition, geographical coordinates are used to spatially analyze measures of field technical efficiency and household average technical efficiency. Performing spatial analysis of field efficiency provides an avenue to test for the significance of environmental shocks on production efficiency. Spatial analysis of household average efficiency provides an alternative to what was previously done in the literature to test for the potential effectiveness of environmental diversification as a risk mitigation strategy. We believe that employing an intuitive methodology as a production frontier to quantity the costs of risk mitigation, using GIS to capture the spatial production environment, and performing spatial analysis of field and household efficiency measures can move forward the literature on risk mitigation and its costs.

The second essay is entitled "Determinants of market participation decisions and marketing choices in Bolivia" and contributes to the literature in two ways. First, this essay examines three aspects of market participation: market entry, volume sold, and market choices. Previous studies have either analyzed market entry and volume sold using a Heckman selection model or market choice. To the best of our knowledge, this is the first study combining the three dimensions. In addition, the literature on market choice is rather thin and the qualitative aspect of market choice is rarely considered. We use second-order stochastic dominance (SOSD) on household average effective prices, which is defined as the market price net of transportation costs, to identify the best market choices for risk averse individuals. Market choices meeting the SOSD criterion are referred to as *optimal marketing strategies* since they have the higher income and lower variance of income. For a risk averse individual employing an optimal marketing strategy will yield higher expected utility compared to other marketing strategies.

The econometric specification is a two-step process taking into account the correlation amongst the error structure of the three equations. The first step consists of estimating a Heckman selection model for the discrete decision of whether to participate in the market, and conditional on market participation, the continuous decision of how much to sell. Then, the Heckman selection model is used to predict quantity sold. The second step examines market choice using a Probit model, where the dependent variable distinguishes between households selecting an optimal marketing strategy from those who did not. Since volume sold is an endogenous regressor in the Probit model, its predicted values are used. A thorough econometric specification, an innovative methodology to assess the qualitative aspect of market choice, and a holistic approach to market participation that considers these three dimensions of marketing decisions, make this second essay unique. The results can better inform policy-makers regarding the use of markets as a tool to lift small-scale farmers out of poverty.

The third essay entitled "A profile of changes in well-being in Zimbabwe, 2001-2007/8, using an asset index methodology" examines inter-temporal and spatial changes in well-being that occurred in Zimbabwe during the 2001-8 period of economic chaos. The lack of nationally representative household data and the period of hyperinflation invalidate the use of conventional money-metric measures of household well-being, such as per capita consumption expenditures. As a result Zimbabwean policy-makers possess insufficient information upon which to make decisions. To address this issue, we use the 2001 and 2007/8 ICES data and refer to the growing literature on asset indices to construct a well-being measure that reflect household long-term economic status. The asset index is constructed using Polychoric Principal Component Analysis (PCA), which is the best methodology to address the categorical nature of several of the variables considered in the index. The advantages of using an asset index methodology are numerous. For example, data requirements are much lower than for consumption expenditures, reducing data collection costs; there is no need to adjust for price differences over time and over space; and the asset index is a closer representation of the permanent income hypothesis and reflects the multidimensional nature of poverty. The third essay shows that the asset index methodology, in addition to providing valuable information concerning the conditions faced by the poor, has great potential in expanding poverty analysis.

The three essays are connected to the common theme of poverty reduction in developing countries. Poverty reduction is a key goal of development assistance and a focus for policy makers in developing countries. However, the basis for informed decision-making is often weak. To provide assistance on this issue, there is a need to come up with new techniques of measuring poverty based on the current availability of data and limited financial resources. Results show that an index asset can be an insightful method to assess well-being changes, providing a promising avenue to measure poverty when consumption expenditures data are unreliable, unavailable, or funds to collect such data are insufficient. Stimulating market participation and access to more lucrative markets are keys in poverty alleviation. Results of the second essay provide policy makers guidance on how to use markets as a tool to lift semi-subsistence farmers out of poverty. Last our results indicate that yield and welfare losses occur as a result of household self-managing risk. Therefore, introduction of enhanced risk management strategies can better enable poor households escaping poverty trap.

ESSAY 1: The role of risk mitigation in production efficiency: A case study of potato cultivation in the Bolivian Andes

Introduction

In a country like Bolivia where formal insurance mechanisms are rare, small-scale farmers rely on a variety of strategies to manage risk. Many environmental risks such as frost, hail, or drought can be mitigated through self-insurance techniques. The literature distinguishes between two types of self-insurance: risk coping and risk management (Alderman and Paxson, 1992). Risk coping refers to strategies that smooth consumption either intertemporally or across households through risk sharing. Intertemporal consumption smoothing can be achieved through saving and borrowing or through asset accumulation and sales. Risk sharing is used to mitigate income shocks at a given time across households within a village. Risk management involves actions to reduce income variability, such as crop, field, and income source diversification.

We focus on the costs of risk management and on how activity and environmental diversification translate into efficiency losses in potato production. For small-scale farmers in the Bolivian Andes, potato is the main crop. However compared to other major potato-producing countries, potato yields in the region are low--about 10.6 tons per hectare--compared to 16.3 and 16.8 tons per hectare in Latin America and worldwide (Alene *et al.*, 2008). Shocks to production in the region include frost, hail, drought, pest infestation, and disease. In order to attenuate environmental risk exposure, producers diversify potato production by cultivating beans, cereals and vegetables; they also own livestock. Risk exposure is also reduced by cultivating potatoes across different microclimatic regions within walking distance of the dwelling. Typically, producers cultivate potatoes in valleys where fields are relatively flat and at higher elevations where fields are sloped. Flat fields are easier to manage, but are more vulnerable to hail and frost shocks than sloped fields. Most households in our study area cultivate fields in different micro-regions.

The effectiveness of self-insurance depends on the nature of risk. In the West Africa context, Carter (1997) examines how activity and environmental diversification can lessen household risk by reducing the impact of microclimatic shocks on the production portfolio variance. While using slightly different language than Alderman and Paxson (1992), the concepts are the same. More precisely, activity diversification (or crop diversification) is defined as cultivating in the same environment crops that respond differently to climatic shocks. Intercropping in a single plot a crop that does well in dry conditions with a crop that performs best in humid conditions is an example. Carter (1997) finds mixed results; in only one of two regions studied, activity diversification was effective in reducing risk exposure. Environmental diversification (or field diversification) involves cultivating the same crop in different microenvironments where risk is not perfectly correlated. Carter finds that environmental diversification reduces household risk in both regions but to a greater extent where shocks are more severe.

Self-insurance techniques have potential to reduce household vulnerability to environmental shocks, but these mechanisms, like formal insurance, are not costless. An important cost of informal insurance is expected yield forgone. Yield is expected to be lower when resources are allocated in order to meet self-insurance goals. Households might cultivate safer traditional varieties as opposed to riskier, high-yielding varieties. Alternatively, they may use purchased inputs less intensively in order to reduce financial risks (Morduch, 1995). Fafchamps (1993) describes these practices as “flexible farming”. Farmers make continuous decisions about labor allocation in response to environmental shocks. Fafchamps (1993) finds that small-scale farmers in Burkina Faso increase their labor effort in response to positive environmental shocks and reduce their labor effort in response to negative shocks. In situations of extreme negative shocks leading to very low marginal productivity of labor, they may reallocate their labor into alternative activities. While there is no direct reference to the costs of dealing with environmental risk, there is strong evidence of flexibility in farming practices in environments characterized by high vulnerability to climatic shocks.

Other costs are associated with activity and environmental diversification. Gains from specialization can be lessened or lost through activity diversification. Costs of field scattering can include time lost walking between fields and increased transportation costs (Carter, 1997).

While risk management is frequently discussed in the development literature, the costs associated with it are not commonly measured. Carter (1997) estimates the insurance premium households are willing to pay in order to reduce the variability of their production portfolio, using expected utility, risk aversion, and certainty equivalent concepts. However, he could not econometrically assess the cost of risk management in the form of yield forgone. Our approach is intuitive and allows us to quantify costs of risk management in terms of efficiency losses, which are easily converted into yield losses.

The objectives of this study are (i) to quantify the costs of environmental and activity diversification in the form of yield forgone, (ii) to spatially analyze production vulnerability to environmental shocks, and (iii) to assess the potential of environmental diversification as a self-insurance strategy. We estimate a stochastic production frontier and model the mean of inefficiency as a function of environmental and activity diversification. We find that efficiency decreases with the number of fields in a geographic cluster, distance between the dwelling and a particular field, discontinuity between fields, and degree of crop diversification. All measures of environmental diversification are associated with efficiency losses of less than one percentage point, while crop diversification reduces average efficiency by 6.2 percentage points, a yield loss of 1170 kg/ha.

To show where shocks occur and assess the potential of environmental diversification in mitigating risk, spatial analyses of field and household efficiency measures are performed. We find important spatial clusters of low and high efficiency at the field-level, confirming the presence of climatic shocks and how those are microenvironment-specific. Last, household average efficiency measures exhibit random spatial patterns, supporting the hypothesis that households can mitigate adverse effects of shocks through environmental diversification.

Theoretical framework

Our theoretical framework describes how farmers manage environmental risk though activity and environmental diversification and respond to climatic shocks. We assume that households have a production portfolio Y defined as:

$$Y = \sum_{i=1}^{N} \alpha_j y_j \qquad (1)$$

N is the number of plots a given household cultivates, α_j represents the proportion of land area of each plot, and y_j is the output associated with plot j. For each plot, households determine which crops to plant and the amount of inputs to allocate. These decisions are based on expectations about plot productivity, yield variability, and desire to manage risk.

$$\mu = E(Y) = \sum_{j=1}^{N}[\alpha_j E(y_j) \tag{2.a}$$

$$\sigma^2 = \sum_{j=1}^{N}\alpha_j^2\sigma_j^2 + \sum_{j=1}^{N}\sum_{k\neq j}^{N}\alpha_j\alpha_k\sigma_j\sigma_k\rho_{j,k} \tag{2.b}$$

Equation 2.a indicates that the household production portfolio mean (μ) return is the sum of each plot's production (y_j) weighted by its respective land share (α_j). In equation 2.b, the portfolio variance (σ^2) varies with the proportion of land area (α_j), plot production variance (σ^2_j), and the correlation coefficient $\rho_{j,k}$, which captures the correlation between two plots' production. By choosing a combination of activities that have low or negatively correlated returns (i.e. $-1 \leq \rho < 1$), the portfolio variance will be less than the sum of individual field variances, implying that diversification can reduce risk exposure. Households are assumed to be risk averse and consequently, for production portfolios with identical means, the portfolio with the smallest variance will be preferred.

The household objective is to maximize the expected utility of profit of the production portfolio (Equation 3.a) subject to a cash (Equation 3.b) and variance constraint (Equation 3.c).

$$EU(\sum_{j=1}^{N} y_j P_{y_j} - \sum_{j=1}^{N} x_j P_{x_j}) \tag{3.a}$$

$$\sum_{j=1}^{N} y_j P_{y_j} \geq \sum_{j=1}^{N} x_j P_{x_j} \tag{3.b}$$

$$\sum_{j=1}^{N}\alpha_j^2\sigma_j^2+\sum_{j=1}^{N}\sum_{k\neq j}^{N}\alpha_j\alpha_k\sigma_j\sigma_k\rho_{j,k}\leq s \tag{3.c}$$

P_{Yj} represents the price received for plot *j*'s production (y_j), and x_j and P_{Xj} are the input quantities and costs allocated to plot *j*. The cash constraint ensures that revenues ($\Sigma y_{j*}P_{Yj}$) from the production portfolio are equal to or superior to the summation of all input costs (x_j*P_{xj}). The variance constraint specifies that the production portfolio variance is less than or equal to *s*, where *s* is the variance level that insures that the production portfolio *Y* will yield with a certain probability sufficient returns to meet subsistence needs (Stanley, 2007). This constraint is similar to the safety-first principle introduced by Roy in 1952. In order to meet the variance constraint, households can resort to two risk management strategies: activity diversification and environmental diversification. For simplicity, we assume that households are concerned with managing production risk only[1].

However, managing the variability of the production portfolio can be costly since it restricts the ability to maximize production. We hypothesize that the optimal production level is not always achieved because of diversification strategies, resulting in inefficiencies in production (deviations below the optimal output level defined by the production frontier). Our hypothesis is consistent with the risk efficiency hypothesis, which stipulates that risk affects technical and allocative efficiency. The risk-efficiency hypothesis also requires that the dynamic structure of agricultural production is taken into account (Antle, 1983a). Modeling the dynamics of the production process allows us to

[1] Farmers provide most of the inputs, such as seeds and labor, themselves and do not rely heavily on the agricultural markets being engaged mainly in semi-subsistence farming.

reflect the fact that farmers resort to flexible farming practices to deal with environmental risk (Fafchamps, 1993).

We model a field-level production function for potato yield as a two-stage dynamic process (Antle, 1983a). During the first stage, land preparation and planting decisions are made, and in the second stage, crops are managed and harvested. Output in the second decision stage (y_{j2}) depends on output in the first stage (y_{j1}) (Equation 4.b), which implicitly depends on previous input allocations (Equation 4.a). We focus on potato production as plots devoted to potato cultivation represent a large share of the households' production portfolio. This specification allows us to assess the impact of activity diversification, such as bean cultivation and livestock production, on potato productivity.

$$y_{j1} = f(x_{j1}) \qquad (4.a)$$

$$y_{j2} = y_{j1} + f(x_{j2}|\theta_j) \qquad (4.b)$$

$$y_j = f(x_{j1}) + f(x_{j2}|\theta_j) \qquad (4.c)$$

In stage 1, the household allocates inputs x_{j1} to plot j to maximize expected profit given prices of x_{j1} and y_j, the variance constraint, and expectations about y_j. Producer expectations in stage 1 denoted as $E_1(y_j)$ have a probability distribution shaped by previous shocks and plot-specific agro-ecological conditions, such as elevation and soil fertility. Once planting decisions have been made but before the start of period 2, filed-specific shocks (θ_j) occur. After the shocks, producers update their expectations about y_j, and adjust farming practices accordingly. More precisely, in stage 2 the household selects the optimal combination of inputs to maximize expected profit based on input and output prices, the variance constraint, and its new expectations about y_j, $E_2(y_j)$, where $E_2(y_j)$ has a probability distribution conditioned by realization of the shocks.

Consider decisions about two fields. Assume that in *t=1* the production functions for *Field j and Field k* are identical such that farmer's expectations about outputs are the same for both fields. This implies equal marginal products across fields given input levels and identical input application in stage 1. Assume that shocks occurring between *t=1* and *t=2* cause *Field k's* production function to shift downward. Consequently in *t=2, Field k* expected output $E_2(y_k) = f(x_{k1}) + f(x_{k2}|\theta_k)$ is lower than *Field j* expected output $E_2(y_j) = f(x_{j1}) + f(x_{j2}|\theta_j)$, causing the marginal product of inputs in *Field K* to be lower across the whole range of inputs. The optimizing producer will reduce input application in this field, resulting in fewer inputs applied in *Field k* in comparison to *Field j* in stage 2.

In our model, input demands depend on farmers' expectations about output. Since $E_t(y_j)$ is nonstochastic, we can assume that input and output are independent and can estimate this sequential decision-making process with a single-equation as long as the error terms between the input demand functions and production function are independent (Antle, 1983b). This assumption is plausible since the input demand function error terms are likely to reflect human acts, such as human mistakes while the production function random error term is more likely to be the reflection of nature (Zellner *et al.*, 1966).

To best represent the first component of the risk-efficiency hypothesis (risk affects technical efficiency), we employ a stochastic production frontier to model the dynamic nature of potato production. This specification allows us to capture the costs of activity and environmental diversification in the form of efficiency losses. Stochastic frontier analyses, since first introduced by Aigner *et al*. (1977) and Meeusen and van den

Broeck (1977), have evolved tremendously and various specifications are now available. We employ the stochastic production frontier proposed by Kumbhakar *et al.* (1991), Huang and Liu (1994), and Battese and Coelli (1995), referred to as the KGMHLBC model. We assume that the production technology takes the form of a Cobb-Douglas stochastic production frontier (Equation 5.a). Additional assumptions behind the KGMHLBC model are: (i) the random error term v_j has a normal distribution with mean zero and variance σ^2_v (Equation 5.b); (ii) the inefficiency term u_j has a truncated-normal distribution with a mean expressed as linear combination of the covariates z_j, and a variance equal to σ^2_u (Equation 5.c).

$$ln\ y_j = ln\ f(x_{j1}, x_{ij2}|\theta_j; \beta_{j1}, \beta_{j2}) + v_j - u_j \quad (5.a)$$

$$v_j \sim N[0, \sigma^2_v] \quad (5.b)$$

$$u_j \sim N^+[\delta z_j, \sigma^2_u] \quad (5.c)$$

Equation (5.c) stipulates that the mean of u_j can be modeled as a function of exogenous variables z_j, such that $u_j = \delta z_j$; this expression is referred as the inefficiency model. The variables z_j influence the efficiency by which inputs are converted into outputs. For example, if efficiency across farms is believed to vary according to manager abilities, manager education and experience could enter the inefficiency model. We hypothesize that household ability to manage a given plot depends on the degree of activity and environmental diversification. Using this assumption, we model the mean of u_j as a function of activity and environmental diversification measures.

Activity diversification lessens specialization in potato production, adversely affecting a household's ability to manage its potato fields. Environmental diversification, which results in field scattering, can increase transaction costs associated with field management reducing productivity. For example, a pest outbreak could go unnoticed at its early stage in more distant fields if they are monitored less frequently than fields located near the house. Moreover, after walking long distances to reach more distant fields, labor may not be as productive as when working on nearby fields. Farming activities might be performed less frequently (but not necessary less intensively) in remote fields causing farm management practices to be less effective. Six hours of weeding accomplished over a three-week period at a rate of two hours a week will not have the same impact on yield as six hours of weeding accomplished in a single day.

We hypothesize that inputs might not always yield the maximal feasible output when households resort to diversification strategies, resulting in deviations below the frontier referred as inefficiency. Our first *hypothesis* is that managing the production portfolio through activity and environmental diversification influences the efficiency of the production process and can explain the variations in the mean of u_j.

To test our first hypothesis, we examine the joint significance of the z_j variables (Equation 5.c) associated with activity and environmental diversification using likelihood-ratio (LR) tests. Finding that these variables are jointly significant would support the hypothesis that activity and environmental diversification influence production efficiency. A shortcoming of stochastic production frontiers is that the coefficients in the inefficiency model provide information only on the direction and not on the magnitude of the influence. Since we wish to estimate costs of managing the portfolio variance as outputs forgone due to inefficiency, the magnitudes are needed. For this reason, we estimate marginal effects and elasticities of technical efficiency with respect to the z_j variables (Frame and Coelli, 2001; Rahman and Rahman, 2008).

With distributional assumptions on v_j and u_j (Equations 5.b and 5.c), we obtain measures of production efficiency, eff_j, based on the relationship that $eff_j=E\{exp(-u_j)|e_j\}$, where eff_j is the efficiency measure of plot *j*. Efficiency measures can take values between zero and one and correspond to the ratio of observed production to the maximal feasible output (referred as the production frontier) given a set of inputs. In line with Antle (1983a), we argue that the reallocation of inputs in stage 2 impacts the measure of production efficiency. We assume that a negative shock will be captured in the u_j term and appear as production inefficiency. Referring to our earlier discussion, shocks caused *Field k*'s production function to shift downward, lowering expected output in stage 2. This results in lower marginal products and fewer inputs to be applied. Since the efficiency measure is influenced by inputs applied in both stages, and inputs applied in $t=1$ did not yield the anticipated output $E_1(y_k)$, we expect *Field k's* estimated efficiency measure to be low. Efficiency in risk management is disguised as production inefficiency. Similarly, we expect to observe relatively high measures of efficiency in plots where positive shocks occurred. The *second hypothesis* is that shocks and input reallocation following these shocks influence production efficiency measures eff_j.

To assess the *second hypothesis*, we analyze the spatial patterns of efficiency measures based on the assumption that fields located in the same microenvironment are affected by similar shocks and have similar efficiency measures. By examining spatial patterns of efficiency, we observe where shocks occurred. We expect to observe spatial clusters of low efficiency where negative shocks occurred and high efficiency where positive shocks occurred. Moreover, a negative shock in one microenvironment (leading to fewer inputs such as labor to be applied) might give households the opportunity to better manage the remainder of their plots, resulting in higher efficiency measures in the latter. We use Global Moran's I statistics to test for the presence of spatial clustering within the study area. The Global Moran's I is a global statistic for spatial autocorrelation based on variable locations and values. The null hypothesis is that the data do not exhibit any spatial pattern or in other words, the values are randomly distributed. Rejection of the null with a positive z-score indicates that observations with similar values are clustered spatially while rejecting the null with a negative z-score indicates dispersion of similar observations (Ouma *et al.*, 2010). Rejecting the null with a positive z-score would indicate that field efficiencies are spatially clustered, supporting the hypothesis that shocks affect efficiency and that households respond to these shocks. Since a global statistic does not answer the question of where the spatial clusters are located, the Local Getis-Ord Gi* (hot spot analysis) is used to visualize clusters of high and low efficiency when a positive z-score for the General Moran's I statistic is obtained (Shilpi and Umali-Deininger, 2008).

Our *third hypothesis* states that environmental diversification can be an effective strategy in attenuating climatic shocks affecting potato production. We expect fields located in different microenvironments to be affected by different shocks and as a result, yield between fields to be weakly or negatively correlated. To explore our third hypothesis, we exploit the differences between the spatial patterns of field efficiency and household efficiency. Since households cultivate generally more than one plot, a measure of household efficiency can be calculated.

$$eff = \frac{\sum_{j=1}^{N} \alpha_j eff_j}{N} \qquad (6)$$

Equation 6 indicates that the house-specific efficiency measure, *eff*, depends on plot areas (α_j), plot efficiency measures (eff_j), and N, the total number of potato plots cultivated by the household. While we expect fields located near each other to have similar efficiency measures, we do not expect households located nearby to have correlated measures of efficiency. Even if adjacent households are likely to have similar characteristics, they are unlikely to cultivate potatoes in the same microenvironments and this is especially true for fields located at higher elevations. Therefore, we expect less pronounced spatial patterns of efficiency when the spatial analysis is conducted at the household-level compared to the field-level. As with our second hypothesis, we employ the Global Moran's I to test for spatial autocorrelation where the variables of interest are household location and its corresponding measure of efficiency. Failing to reject the null hypothesis indicates that household-level efficiency measures are randomly distributed over space supporting our third hypothesis that risk exposure can be attenuated through environmental diversification.

Data

In 2006/7, 284 Bolivian producers in Tiraque Province, Cochabamba Department (Figure 1), were randomly interviewed. Steep mountainous terrain with slopes ranging from 10 to 40 percent and elevation between 3000 and 4500 meters characterize the area. Households are organized into 14 communities that comprise approximately 3,000 inhabitants. The 14 communities are located on each side of a paved road between Cochabamba and Santa Cruz, two major cities. Ease of access to the communities and dwellings is variable and depends on their location relative to the paved road. Off the road, transportation is limited and dirt roads are of poor quality. Consequently, isolation increases with distance to the paved road.

[Figure 1]

The survey covered household demographics and composition, agricultural activities and equipment, household revenues and expenses, gender division of labor, and others. The longitude and latitude of each dwelling were recorded. In order to obtain the geographical coordinates of the potato fields[2], additional fieldwork was performed. A satellite image of the study area was divided and printed into maps. Farmers were asked to locate their potato fields on these maps. Many farmers were unwilling to reveal these details, so the final sample size included 293 geo-referenced potato fields belonging to 124 households.

The satellite image, purchased from the Instituto Militar de Ingenieria in Bolivia, is a raster dataset of IMAGINE Image with cells of one meter squared resolution. The area of each potato plot was digitalized on this satellite image (ArcGIS 9.3.1), and field longitude and latitude were extracted based on the plot center. Field coordinates were combined with two GIS data layers: i) a digital elevation map (DEM) downloaded from the Shuttle Radar Topography Mission (SRTM) website[3] and interpolated using the Spline methodology to obtain cells of 30 meters resolution (Her and Heatwole, 2008), and ii) a shape file[4] of the soil characteristics of the area. By combining field coordinates with GIS data, we obtain the elevation and severity of soil erosion for each plot. We also used the satellite image to digitize the dirt roads and compute travel path-based distance

[2] Farmers in the original survey were reluctant to reveal the locations and sizes of potato fields.
[3] http://srtm.usgs.gov/
[4] This shape file was created by a GIS professional working for the PROINPA foundation based on a regional soil map and area coordinates.

measures, such as distance between fields and distance between the dwelling and a particular field.

Empirical specification

The technology for potato production is represented by a Cobb-Douglas stochastic production frontier (Equation 7.a); the inefficiency model is defined by Equation 7.b.

$$\ln y_j = \beta_0 + \sum_{j1=1}^{k} \beta_{j1} \ln x_{j1} + \sum_{j2=k+1}^{j} \beta_{j2} \ln x_{j2} + \vartheta_j + \sum_{l=j+1}^{m} \beta_l \ln q_j + v_j - u_j \qquad (7.a)$$

$$u_j = \delta_0 + \sum_{n=1}^{k} \delta_n ED_j + \sum_{k+1}^{l} \delta_k AD + \sum_{l+1}^{m} \delta_l HHH \qquad (7.b)$$

y_j represents potato yield in kilograms per hectare (kg/ha) households obtained in the j^{th} plot and is a function of agricultural inputs applied in both periods. Inputs considered in the first stage are seeds (kg/ha), fertilizer (kg/ha), and labor (hours/ha). Inputs in stage 2 are the number of pesticide applications, fertilizer, and labor. We control for the role of field-specific agro-ecological conditions, which affect both yield and risk exposure, by including in the production frontier the elevation and level of soil erosion of each plot. We also include a variable for seed size to quantify the role of seed quality on production. These three variables are denoted by the symbol q_j in Equation 7.a. Studies from Bolivia show that higher elevation leads to higher potato yields in all departments (Terrazas *et al.*, 1998). This finding is attributable to lower late blight infestation at higher altitude. Late blight infestation is less of a problem at higher altitude because these plots have only been cultivated recently and the climate is drier. However, plots at higher elevation are more subject to frost damage, making the influence of elevation on yield unknown. To capture the synergy between elevation and reduced pest pressure, an interaction term between elevation and the number of pesticide applications is included in the model. Soil erosion in the study area varies from light to moderate, moderate, and moderate to heavy. A dummy variable representing the last category is included in the frontier to quantify its effect on yield. Since seed quality is a crucial determinant of potato yield, we include a dummy variable for seed tuber size; small tubers tend to produce higher yields than large tubers since cutting large tubers is more likely to result in blind seed pieces (Bohl *et al.*, 1995). Definitions of the variables included in the stochastic production frontier and inefficiency model are reported in Table 1.

[Table 1]

Inefficiency in production, represented by equation 7.b, is modeled as a function of environmental diversification (ED), activity diversification (AD), and characteristics of the household head (HHH). Since our focus is the costs of risk management, measured by production efficiency losses, it is worth providing a detailed description of each variable included in the inefficiency model. The first measure of environmental diversification is the number of field clusters cultivated by a given household. We define field clusters as circles of 600 meters in diameter[5], equivalent to 282,744 m^2. Households normally have field clusters at different distances to the main residence. We commonly observe one cluster of fields nearby the dwelling and a second at higher elevation. Households have secure rights to land use resulting in households cultivating the same plots for many years. In a region characterized by steep mountains, a variation of 600 meters can be associated with important fluctuations in agro-climatic conditions such as temperature, soil fertility, and rainfall. The greater the number of clusters a household cultivates, the greater the environmental diversification. The second measure of

[5] While determining clusters in ArcGIS, we ensure that for a given household clusters do not overlap.

environmental diversification is the number of fields per cluster. This variable captures the impact of land fragmentation on efficiency. Monchuk *et al*. (2010) show that land fragmentation can have a detrimental effect on output.

We modify the concept of effective distance introduced by Monchuk *et al*. (2010) since their measure captures discontinuity between fields *as well as* discontinuity between the dwelling and a particular field, while we are interested in the role both measures have on efficiency. For this reason, we include in the inefficiency model the distance between the dwelling and a particular field as one variable and the effective distance as a second variable. We define effective distance as a measure of discontinuity between fields only, which is calculated as follow.

$$Eff\_Dist_j = \frac{\sum_{j=1}^{N} dis_{j,j+n}}{N-1} \tag{8}$$

$dis_{j,j+n}$ represents the distance (in kilometers) between plot j and plot $j+n$ and N is the number of plots the household devotes to potato production. A small effective distance indicates that a particular plot is located near or connected to other household potato plots, where a large effective distance implies that a particular field is disconnected from other potato plots. As effective distance increases, transaction costs related to field monitoring and input transportation increase, which can adversely influence farming practices and efficiency. The squared terms of the four measures of environmental diversification are included to control for potential nonlinearities between these variables and inefficiency.

Two variables capturing the influence of activity diversification are included in the inefficiency model: i) the ratio of potato to total crop revenue to measure specialization in potato production by indicating how heavily a particular household relies on potato sales for income, and ii) a dummy variable indicating whether a given household reported revenue from livestock production. By dedicating time to other activities such as cereals or livestock production, less time is left to devote to potato production. Activity diversification can cause inefficiency if poorer management practices result or accumulation of knowledge relatively to potato cultivation is lost.

To conform with previous studies on inefficiency and control for managerial abilities, we include characteristics of the household head (age, education, and gender) in the inefficiency model. The age of the household head would decrease inefficiency if older farmers are more experienced and knowledgeable about agricultural production than younger farmers (Battese *et al.*, 1996; Ahmed *et al.*, 2002). Alternatively, age could increase inefficiencies if older farmers are more reluctant to adopt new technologies while younger farmers welcome these innovations (Villano and Fleming, 2004; Boshrabadi *et al.*, 2006). We expect a positive relation between efficiency and household head education, where education is proxied by a literacy dummy variable (Ahmed *et al.*, 2002).

The ratio of potato to total crop revenue is possibly endogenous to inefficiency since farmers who achieve higher measures of efficiency are also more likely to obtain greater shares of income from potato sales. For this reason, we instrument this variable using dummy variables representing the 14 communities in the study. Community-specific agro-ecological conditions should affect the choice of crops, and thus the type of sale, but the community in which a farmer resides should not influence yield or efficiency once other factors are account for in the econometric model. The p-value of the F-test statistic for the joint significance of the instruments is inferior to 0.01 percent indicating the relevance of the instruments. The R^2 from the instrumental regression is 0.25 suggesting a good correlation between the instruments and the ratio of potato to total crop revenue and an unlikely problem of overfitting. Since our model is nonlinear, the residuals of the instrumental regression are included in the inefficiency model as a means to control for potential endogeneity following the method presented in Cameron and Trivedi (2009a).

To examine our first hypothesis, three LR tests are performed. We test whether the influences of environmental and activity diversification on inefficiency are jointly significant when analyzed together (H_0: $\delta_n = \ldots = \delta_k = \delta_{k+1} = \ldots = \delta_l = 0$) and then test whether each diversification strategy is jointly significant on its own (H_0: $\delta_n = \ldots = \delta_k = 0$ and H_0: $\delta_{k+1} = \ldots = \delta_l = 0$) (Equation 7.b). Rejecting the null hypothesis for the first LR test indicates that activity and environmental diversification significantly influences production efficiency. Rejecting the null hypothesis for the second test indicates that environmental diversification influences inefficiency while rejecting the null for the third test suggests that activity diversification has its own impact on inefficiency.

Results

The unknown parameters β and δ in Equations 7.a and 7.b are obtained by estimating simultaneously[6] the stochastic production frontier and inefficiency model through maximum likelihood (table 2). The coefficients of the Cobb-Douglas [7] production frontier represent the output elasticity with the exception of pesticide

[6] Wang and Schmidt (2002) have shown the biases that can result from two-step estimation.
[7] When estimating the Cobb-Douglas production function, the explanatory variables with zero values are handled as suggested in Battese (1997).

application and elevation because of inclusion of the interaction term between the two. Output elasticities with respect to these two variables are reported in Table 3 alone with the marginal effects and elasticities of production and inefficiency.

[Table 2]

Potato yield is highly responsive to the quantity of seeds, as average yield would increase by 6.1 kg/ha if the average quantity of seeds increases by one kg/ha. The coefficient for labor devoted to land preparation and planting is insignificant suggesting that labor applied during the first stage of production has only a limited effect on yield. Devoting an additional hour of labor (per ha) in the second stage of production would increase potato yield by 3.9 kg/ha. Additional application of pesticide at the sample mean of 3.7 applications would increase average potato yield by 217.2 kg/ha. Cultivating potato at 100 meters higher elevation than at the 3,652 meters sample mean would result in a loss of 75.5 kg/ha. The significance of the interaction term confirms the synergy between elevation and reduced pest pressure. Switching from large to small tubers could increase potato yield by 25 percent, corresponding to an increase of 2,662 kg/ha at the sample mean.

[Table 3]

Before discussing the efficiency costs of risk management, an overview of field efficiency measures is provided. The average field-level efficiency measure is 55.97%, which implies that potato yield could be increased by 79% [(1- 0.5597)/0.5597] if inefficiencies were to be eliminated. The minimum (maximum) efficiency measure is 5.84% (94.63%). A full efficiency corresponds to a yield of 19,023 kg/ha in contrast to 10,647 kg/ha with the average efficiency of 55.97%. The low efficiency level is consistent with a dynamic framework where shocks occur and input allocation is adapted. This outcome can be seen as the welfare cost of coping with environmental risk.

To begin the analysis of the costs of risk management, hypotheses and results of LR tests reported in Table 4 are discussed. The null hypothesis that the diversification variables are jointly zero is strongly rejected, meaning that self-insurance in the form of diversification strategies significantly influence production efficiency. Including measures of environmental and activity diversification in the inefficiency model improved its fit, suggesting that the empirical results are consistent with the theoretical framework. The null hypotheses of the effects of environmental diversification and the effects of activity diversification are jointly zero are also rejected at the 1% and 5% respectively. Environmental and activity diversification both impact production efficiency in support of our first hypothesis.

[Table 4]

Having confirmed the joint effects of diversification on inefficiency, we examine each variable to estimate efficiency and yield losses. Of the ten variables representing risk management, six have significant coefficients. The number of fields per cluster and its squared term suggest that inefficiency increases at a decreasing rate with the number of fields per cluster. While this provides evidence of the detrimental effect of land fragmentation on production efficiency, the effect is small. Efficiency would decrease by 0.21% if one plot were added to a given cluster, reducing average efficiency from 55.97% to 55.76%, an average yield loss of about 40 kg/ha. Inefficiency increases linearly with the distance between the dwelling and a particular field, suggesting that transaction costs associated with moving labor and other agricultural inputs from the dwelling to the field results in time lost and output forgone. Every kilometer between the dwelling and a particular field decreases efficiency by 0.37%, representing a potato loss of 71 kg/ha. Effective distance and its squared term are both significant at the 5 percent level, suggesting that discontinuity between fields causes inefficiency. An increase in one kilometer in effective distance would decrease average efficiency by 0.61%, a loss of 117 kg/ha.

Regarding variables associated with activity diversification, the coefficient for the ratio of potato to total crop revenue is statistically significant while the one for livestock revenue is not. This suggests that crop diversification (such as cultivating beans and cereals) is efficiency costly while activity diversification (such as livestock production) is not. This could be because livestock production is minimal in the study area and does not compete with resources allocated to potato production contrarily to the cultivation of other crops. Crop diversification has the most detrimental effect on potato production efficiency, as the ratio of potato to total crop revenue has a marginal effect[8] superior to the marginal effects of all environmental diversification measures. A one percentage point decrease in this ratio (from the current average of 87% to 86%) would decrease average efficiency by 6.15%, a loss of 1170 kg/ha. The residuals variable (represented by U_HAT in Table 2) can be viewed as a latent factor that affects both the ratio of potato to total crop revenue and inefficiency while being the only source of variation between the two. Its coefficient provides an opportunity to test for endogeneity, where the null

[8] By adding predicted residuals from the instrumental regressions, the precision of the estimated coefficient for the ratio of potato revenue to total crop revenue is reduced. The standard error is about four times larger. Since the magnitude of the coefficient is also larger, i.e. more than double, the coefficient remains statistically significant. Cameron and Trivedi (2009) report that larger standard errors and coefficients resulting from controlling for endogeneity are common for cross-section data and occur because the instruments are not strongly correlated with the endogenous variable.

hypothesis is that the regressor is exogenous. Since the coefficient of the residuals has a p-value of 0.23, the null hypothesis is not rejected. The positive coefficient suggests that the latent factor, which has a positive effect on the ratio of potato revenue to total crop, also has a positive effect on inefficiency. Therefore, an increase in the ratio of potato to total crop revenue might not yield the expected efficiency gain suggested by the magnitude of its coefficient since the latent factor works in the opposite direction.

Of the three variables capturing the effects of household head characteristics on inefficiency, two are significant and the null hypothesis that effects of these three variables are jointly zero is strongly rejected. Increased age of the head reduces efficiency at a rate of 0.05% per year, a yield loss of 9 kg/ha. A ten percent increase in the proportion of female-headed households increases average efficiency by 1.2% or yield by 51 kg/ha.

We assess our second and third hypotheses using spatial analyses (Global Moran's I[9]) of field- and household-level efficiency measures. The null hypothesis that field-level efficiencies are randomly distributed is strongly rejected. This indicates that fields located near each other have correlated measures of efficiency, supporting our second hypothesis that environmental shocks affect production efficiency. Under our theoretical framework this effect occurs through the impact shocks have on expected output and farmers' responsiveness to changes in the marginal product of inputs. Since spatial autocorrelation of field efficiency measures is confirmed, a hot spot analysis is

[9] The zone of indifference was selected as the type of spatial relationship, which it is a mixed method between fixed distance band and inverse distance. The spatial weights were standardized based on row standardization, which is recommended when the distribution of the features is potentially biased due to sampling design or because of imposed aggregation scheme. Euclidean distance was the selected distance method.

conducted to visualize clusters of high and low efficiency. Negative z-score values, represented by the square points in Figure 2, indicate clusters of low efficiency; these clusters are referred to as cold spots. High z-score values, symbolized by the triangle points, indicate clusters of high efficiency, represent hot spots. There are three clusters of high efficiency, one large and two small, all located south of the paved road. Clusters of low efficiency are found mainly in the eastern part of the study area.

[Figure 2]

High efficiency clusters are expected to be located where micro-climatic conditions were favorable and should come with increased labor effort. Low-efficiency clusters are expected to be found in micro-regions affected by negative shocks and should be associated with a reduction in labor effort (Fafchamps, 1993). Our data concerning labor effort in the second stage of production are consistent with Fafchamps' findings. On average, households devoted 606 hours of labor per hectare in stage 2. However, for fields located in low efficiency clusters (fields with significant negative z-score), this average drops to 526 hours while for fields located in high efficiency clusters (fields with significant positive z-score), labor effort increases to 674 hours per hectare and this difference is statistically significant at a p-value of 0.002. In addition, a local agronomist reported favorable growing conditions during the 2006/7 agricultural season in the region where the largest hot spot is found. This local expert also mentioned that potato production in this rather flat region is highly vulnerable to frost and hail and frequently damaged. These qualitative observations further suggest that the interactions between agro-ecological conditions and microclimatic shocks are important determinants of production efficiency and highlight the importance of spatial diversification in vulnerable production environments.

Before contrasting the spatial patterns of field and household efficiency measures, we briefly outline their statistical differences. The average household efficiency measure is 52.7%, which is lower than the average field efficiency measure. However, the difference is not statistically significant. The standard deviation of household efficiency (18.1) is significantly lower than the standard deviation of field efficiency (21.6) resulting in a less widely spread distribution for household efficiency. This provides evidence of the effectiveness of environmental diversification in reducing the variability in the household production portfolio.

A similar conclusion is reached when analyzing spatial patterns of household efficiency measures. The null hypothesis that household efficiency measures are randomly distributed is not rejected supporting our third hypothesis spatial diversification can be a useful strategy to attenuate the adverse effects of microclimatic shocks. However, this result provides greater evidence that households as a community can manage risk than households, individually, can lower the variance of their production portfolio by resorting to environmental diversification.

Conclusion

In an environment where formal insurance is rare and vulnerability to climatic risk is high, households resort to self-insurance mechanisms. Adoption of these mechanisms can lower the variance of household production but at a cost of increased apparent inefficiency in production. The average measure of efficiency in the study area is low, i.e. about 56%, which is consistent with an environment characterized by high vulnerability to climatic shocks.

Combining fields and households geographical coordinates to GIS data allowed us to depict the production environment and to control for agro-ecological conditions such as elevation that affect both, risk exposure and efficiency. GIS technology enabled the creation of powerful variables to capture the effects of environmental diversification on production inefficiency. The spatial analyses showed that field-level efficiencies are clustered over space, indicating the influence of shocks and suggesting the relevance of environmental diversification in the studied area.

The cost of risk management is reflected by increased apparent technical inefficiency. A one-unit increase in the number of fields per cluster decreases yield by 40 kg/ha. Yield decreases by 71 kg/ha as the distance between the dwelling and a particular field increases by one kilometer. A one-kilometer increase in the measure of field effective distance results in a yield loss of 117 kg/ha. According to the marginal effects of technical efficiency, the best way to reduce inefficiency would be for producers to fully specialize in potato production. An increase in the ratio of potato to total crop revenue from the current average of 87% to 90% could result in a yield gain up to 3510 kg/ha. This hypothetical situation is associated with various risks such as production vulnerability, price fluctuation, and a heavier dependence on markets for other food items, which could increase food insecurity for vulnerable households.

One possible avenue to attenuate costs linked to environmental diversification with a minimal amount of additional risk would be through reciprocity. Labor exchange can reduce inefficiency by reducing labor time losses and lowering input transportation costs (Carter, 1997). Better transportation infrastructure would reduce inefficiency related to travel distances between the dwelling and a particular field and between fields, augmenting potato yield. Moreover, the costs of environmental diversification could be lessened if households achieve greater flexibility in their farming practices. This could occur if agricultural tasks such as planting, weeding, and harvesting do not have to be performed during the same time window for fields located in different microenvironments. New production technologies such as irrigation schemes, and drought and pest resistant varieties could better allow households to manage their resources over time and reduce vulnerability to environmental shocks.

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Table 1: Summary statistics of the variables included in the stochastic production frontier and inefficiency model

Variables	***Description***	***Mean***	***Std. Dev***	**N**
YIELD	Potato yield (kg/ha)	10,647.47	5,377.10	287
Stochastic production frontier				
SEED	Quantity of seed (kg/ha)	1,383.31	300.64	287
FERT_T1	Quantity of fertilizer (N-K-P kg/ha) in stage 1	212.14	170.94	287
FERT_T2	Quantity of fertilizer (N-K-P kg/ha) in stage 2	136.78	127.76	287
LABOR1	Quantity of labor in stage 1 (hours/ha)	496.68	314.14	287
LABOR2	Quantity of labor in stage 2 (hours/ha)	605.96	345.45	287
PESTAPL	Number of pesticide applications	3.74	1.59	287
ELEVATION	Elevation (meters)	3,652.23	151.39	287
DEROSION	Dummy whether erosion is heavy (1/0)	0.17	0.38	287
DSEEDS	Dummy whether seeds tuber are small (1/0)	0.61	0.49	287
Inefficiency model				
NBCLUSTER_600m	Number of clusters (600 meters diameter)	1.65	0.81	123
NBFIELD_600m	Number of fields per cluster	1.9	1.13	287
DIST_F_HH	Distance between field and residence (km)	1.62	1.98	287
EFF_DIST	Effective distance (km)	1.31	1.67	287
RATIO_P_TC	Ratio of potato to total crop revenue	0.87	0.24	123
DLIVESTOCK	Dummy for livestock revenue (1/0)	0.51	0.5	123
AGEH	Household head age	45.34	14.13	123
LITERACYH	Household head literacy (1.Literate/0.Illiterate)	0.85	0.36	123
GENDERH	Household head gender (1.Female/0.Male)	0.16	0.37	123

*The following filters were to eliminate potential outliers: i) yield exceeding 30 000 kg/ha; ii) seeding rates exceeding 2 600 kg/ha; iii) fertilizer applications exceeding 2 000 kg/ha; iv) labor applications equals to zero or exceeding 5 000 hours/ha. Our final sample includes123 households and 287 fields.

Table 2: Results of the stochastic production frontier and inefficiency model

	PRODUCTION FRONTIER		INEFFICIENCY	
Variables	**Coefficients**	**p-values**	**Coefficients**	**p-values**
LN(SEED)	0.788***	0		
LN(FERT_T1)	0.034	0.565		
LN(FERT_T2)	-0.036	0.636		
LN(LABOR1)	0.049	0.484		
LN(LABOR2)	0.220***	0.001		
LN(PESTAPL)	21.946**	0.049		
LN(ELEVATION)	3.084**	0.045		
DEROSION	-0.088	0.157		
DSEEDS	0.250***	0		
LN(PESTAPL) X LN(ELEVATION)	-2.666**	0.049		
RATIO_P_TC			-1.646*	0.071
DLIVESTOCK			-0.113	0.342
NBCLUSTER_600m			0.349	0.437
NBCLUSTER_600m SQ			-0.176	0.139
NBFIELDS_600m			0.358*	0.084
NBFIELDS_600m SQ			-0.073*	0.073
DIST_F_HH			0.138*	0.065
DIST_F_HH SQ			-0.01	0.267
EFF_DIST			0.319**	0.026
EFF_DIST SQ			-0.052**	0.031
AGEH			0.014***	0.007
LITERACYH			-0.24	0.147
GENDERH			-0.340*	0.058
U_HAT			1.115	0.237
CONSTANT	-23.089*	0.07	1.028	0.185
Gamma	2.738***	0		
LN(sigma2)	-1.133***	0		
Log likelihood	-150.89931			
Number of observations	287			

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 3: Elasticity and marginal effect for the production variables and elasticity, marginal effect, and yield effect for the efficiency variables

	PRODUCTION		**EFFICIENCY**		
Variables	**Elasticity (%)**	**Marginal effect (kg/ha)**	**Elasticity (%)**	**Marginal effect (%)**	**Yield effect (kg/ha)**
SEED	0.788	6.065			
LABOR2	0.220	3.866			
PESTAPL	0.076	217.158			
ELEVATION	-0.259	-0.755			
DSEEDS	0.250	2661.868			
NBFIELD_300m			-0.0071	-0.0021	-39.9638
DIST_F_HH			-0.0107	-0.0037	-70.6324
EFF_DIST			-0.0143	-0.0061	-116.7445
RATIO_P_TC			0.0986	0.0615	1170.1858
AGEH			-0.0377	-0.0005	-9.0347
GENDERH			0.0027	0.012	51.2312

Table 4: Hypotheses and test results

Null Hypotheses	**Statistics**
1. Efficiency effects of all diversification variables are jointly zero	($H0: \delta1= \ldots= \delta10=0$)
LR test statistic ($\chi2$)	50.29
Degrees of freedom	12
p-value (Prob. > $\chi2$)	0
Decision	Reject
2. Efficiency effects of all environmental diversification variables are jointly zero	($H0: \delta1=\ldots= \delta8=0$)
LR test statistic ($\chi2$)	24.75
Degrees of freedom	9
p-value (Prob. > $\chi2$)	0.0033
Decision	Reject
3. Efficiency effects of all activity diversification variables are jointly zero	($H0: \delta9=\delta10=0$)
Likelihood ratio test statistic ($\chi2$)	9.78
Degrees of freedom	3
p-value (Prob. > $\chi2$)	0.0205
Decision	Reject
4. Efficiency effects of all household characteristics variables are jointly zero	($H0: \delta11=\ldots= \delta13=0$)
Likelihood ratio test statistic ($\chi2$)	13.27
Degrees of freedom	3
p-value (Prob. > $\chi2$)	0.0041
Decision	Reject

Figure 1: Map of Bolivia by Departments and Provinces

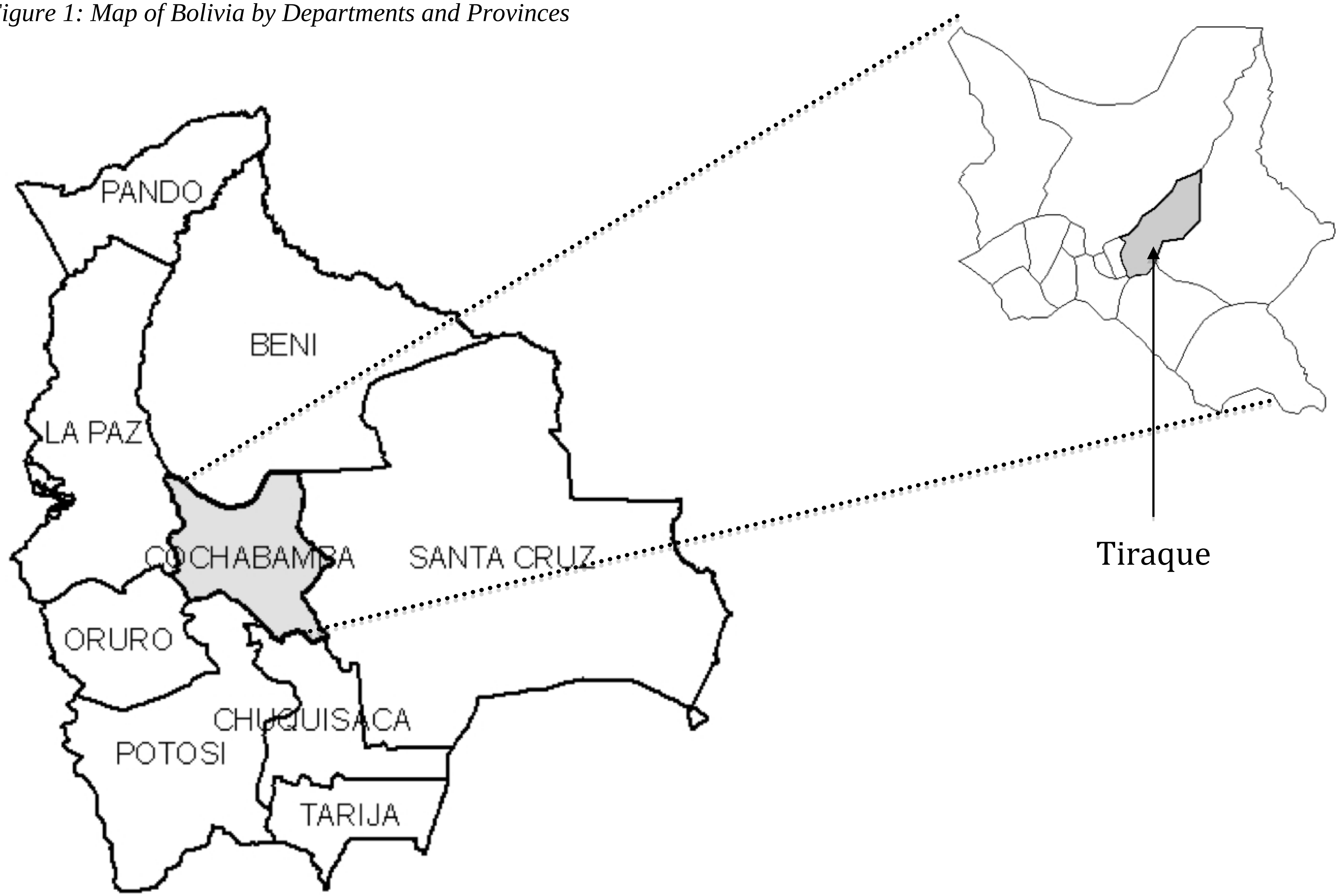
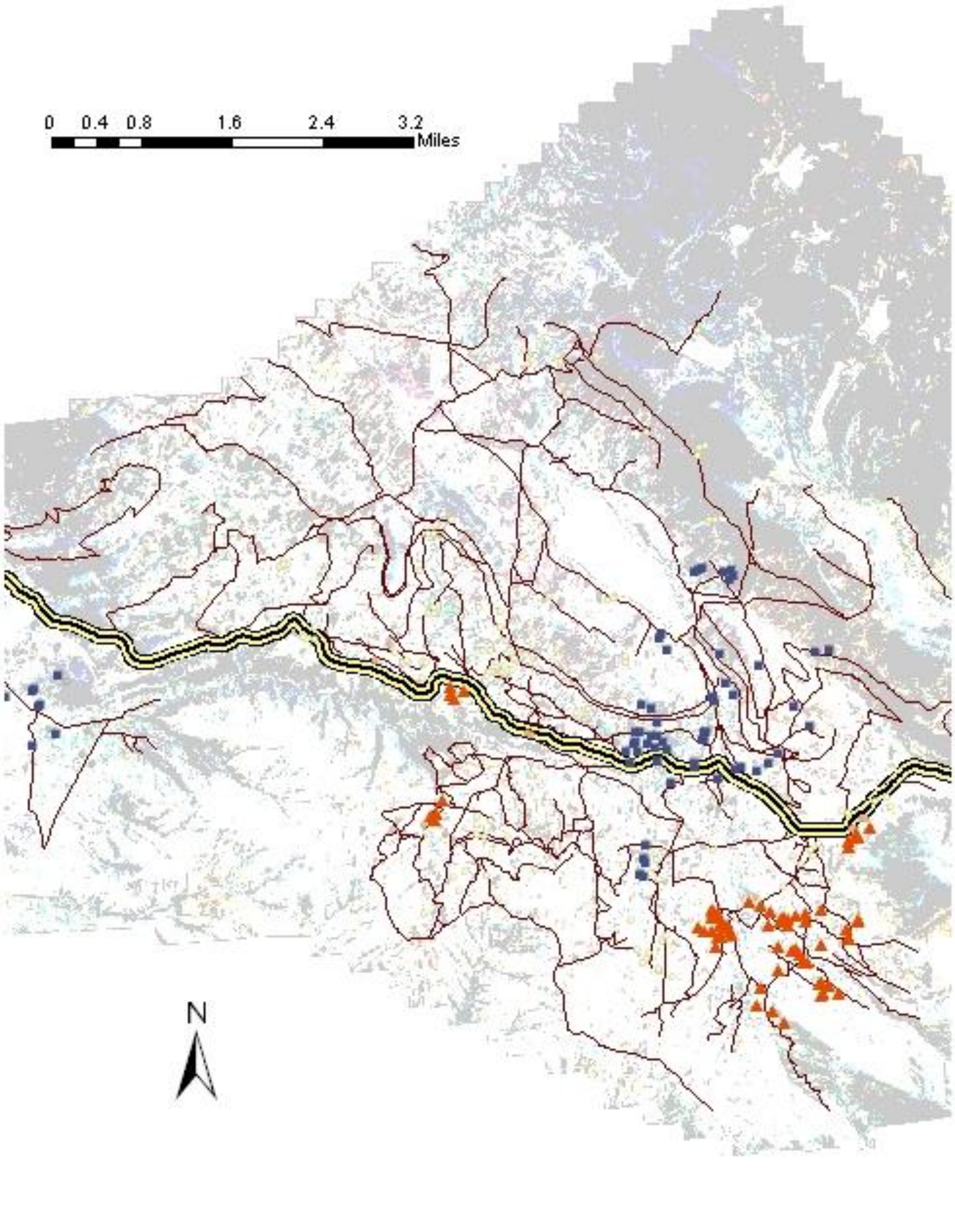


Figure 2: Hot spot analysis for field-level efficiency



ESSAY 2: Determinants of market participation decisions and marketing choices in Bolivia

Introduction

Participation in agricultural markets is recognized as a sustainable path by which small-scale farmers can move out of semi-subsistence farming and poverty. Markets are important engines for economic development. However, it is important to ensure that markets are accessible to the poor so that they can benefit from economic growth associated with market liberalization. A successful transition from subsistence agriculture to a more market-oriented agriculture will benefit rural and urban households. Agricultural market participation, by contributing to poverty alleviation in rural areas, will limit rural-urban migration and increase food supplies. As a result, demand on limited and poor infrastructure found in many cities in developing countries will lessen, benefiting millions of urban citizens. Since market access is a powerful tool for poverty alleviation, determinants of participation and factors affecting quantity sold in markets need to be better understood.

Market participation alone is not sufficient for households to fully enjoy gains from trade. As Boughton et al. (2007) state, there are “sharp differences in the apparent returns to participation in different markets” (p.65). Studies on market choice, while less common than studies on market participation, provide valuable information regarding factors explaining sales in more remunerative markets. For example, Fafchamps and Hill (2005) identify factors distinguishing between the decision to sell at the farmgate (less remunerative) or travel to market (more remunerative). These type of studies are keys to poverty alleviation since as stated by the authors price received can make a difference between poverty alleviation and poverty trap (Fafchamps and Hill, 2005)

Most extant studies analyze market participation decisions or market choices. Having a rich household data set from Bolivian potato producers and GIS data, we propose to study two dimensions of household commercialization decisions: market participation and marketing choices. Our study's objectives are: i) Identify barriers to market entry ii) Identify factors influencing volume sold in markets, and iii) Identify determinants of participation in more lucrative markets. We find that transaction costs faced by the household are the main barrier to market entry. Land holding, which determines marketable surplus, has the greatest impact on volume sold. Farmers selling in distant markets as opposed to selling in only local markets achieve higher incomes without increasing price-related risk. Geographic isolation and lack of liquidity appear to be the main restricting factors for entering into more remunerative markets.

The rest of this paper is divided as follow. Concepts and prior studies on market participation and market choice are presented in the following section. Section three describes the survey area and data on potato production and commercialization. The fourth and fifth sections present the conceptual framework and empirical models. The econometrics results are presented and discussed in the sixth section. Our paper ends with policy recommendations, which can be found in the last section, with our conclusions.

Literature review

In this section, concepts relevant to the study are presented and reviewed. The objective is not to provide an exhaustive review of the market participation literature but to provide a foundation for our conceptual framework and to support our econometric specifications.

Transactions costs can constrain market participation. The literature considers two types: fixed and proportional transaction costs, both of which can potentially restrict market participation. Fixed transaction costs are transaction-specific and do not vary with the quantity sold, while proportional transactions costs are volume dependent. Examples of fixed transaction costs relevant to crop markets are search costs (e.g. for market price information or looking for a buyer), negotiation costs, and costs of enforcing contracts. The biggest proportional transactions cost is the unit cost of transporting the crop to the market.

Transaction costs, in addition to being a financial burden to market participants, can lead to missing markets, i.e. when the costs of market participation outweigh the benefits, causing households not to join the market. This occurs because of the wedge created around the market price, causing the effective price received by the seller to be lower than the market price (Goetz, 1992). The existence of transaction costs also mean that a minimal quantity must be sold in order to cover the lump sum fixed transaction costs associated with market participation and make the decision to join the market profitable (de Janvry and Sadoulet, 2006). Missing markets can occur when transaction costs are high or marketable surplus low making it impossible to cover fixed transaction costs.

In the market participation literature, Goetz (1992) was the first to differentiate between the decision of whether or not to participate in the market (discrete decision) from the decision of how much to sell (continuous decision). By introducing two dimensions of the marketing decision, variables affecting the decision of whether or not to participate in the market can differ from those affecting how much to sell. The same variable can impact each decision differently. Variables used by Goetz are prices, factor capturing productivity capacity, household characteristics such as household size, dependency ratio, ethnicity, and age of the household head, and proxies for transaction costs. By using a two-step model, Goetz also addresses the selectivity issue that can arise when unobserved characteristics affect both the discrete (first-stage) and continuous (second-stage) decision, causing the OLS parameters in the second stage to be biased.

Key et al. (2000) build on Goetz's work and contribute to the literature by identifying the role of fixed and proportional transactions costs on marketing decisions. These authors present a semi-structural model showing that both fixed and proportional transaction costs impact market participation but that the supply decision (i.e. how much to sell), which is conditional on market participation, is affected only by proportional transaction costs. The major implication arising from this study is that fixed transaction costs can be used to identify factors affecting selection into market sales.

Several authors have built on the work of Goetz and Key *et al.* to study determinants of market participation for semi-subsistence farmers. Heltberg and Tarp (2002) analyze marketing behavior in Mozambique using a two-step decision process where market participation is identified by excluding fixed transaction costs from the quantity equation. Three selection models are estimated to distinguish between total sales, food crops sales, and cash crop sales in the second regression. The total sales model is re-estimated to differentiate between behavior of poor and non-poor farmers. The authors conclude that risk and access to technology have the greatest impact on commercialization outcomes.

The task of quantifying impacts of fixed transaction costs on marketing decisions is more complex than for proportional transaction costs. Proportional transaction costs can be directly measured (through transportation costs) while fixed transaction costs cannot, and depend on farmers' access to market information, opportunity costs of time, and so on. Some researchers have avoided this issue and indirectly quantified fixed transaction costs. Vakis *et al.* (2003) estimate the value of market price information using potato transaction sales from Peruvian farmers. Transactions occur at one of two local markets, one of two distant markets, or at the farmgate. The authors conclude that market price information has a substantial value, representing 77 percent of the average effective price. Renkow *et al.* (2004) develop a conceptual framework to quantify fixed transactions costs, expressed as a tax equivalent, that semi-subsistence Kenyan maize farmers face. The fixed transaction costs tax equivalent is defined as the "amount that a household must receive over its autarky price in order to cover the fixed transaction costs of market entry" (p.352). They find that on average the fixed transactions costs equivalent is 15 percent, much lower than the value estimated by Vakis *et al.* (2003). Renkow *et al.* (2004) also find that fixed transactions costs are positively associated with economic isolation, captured in their study by the distance to the nearest market and ownership of transportation means such as animals or bicycles.

While the literature on market participation is quite abundant, research on market choices is rather thin. An influential study is Fafchamps and Hill (2005) who examine Ugandan coffee farmers decisions of whether to sell at the farm-gate or travel to the market. The authors find that the probability of selling at the market is positively associated with the quantity sold and proximity to the market. Wealthier farmers are less likely to sell at the market, suggesting that they have higher opportunity costs of time than poor farmers. However, when an interaction term between wealth and quantity sold is added, the authors find that as quantity sold increases, poor farmers are less likely to travel to the market and wealthier farmers are more likely, suggesting that liquidity constraints restrain poor farmers. An interaction term between wealth and distance to the market confirms this assumption. As distance to the market increases, only the wealthier farmers go to the market since liquidity is required to cover transportation costs. Wealthier farmers are also more likely to travel to distant markets.

Boughton *et al.* (2007) use an asset-based approach to determine if participation in higher-return markets requires a different asset portfolio than participation in less remunerative markets for Mozambique farmers. Three crops were considered: i) maize, whose market is a spot market for staple food characterized by high transaction costs and low returns; ii) cotton, where the market is a contracted cash crop with moderate risk and low transaction costs; and iii) tobacco which is a contracted production-market system with potential higher financial returns and risk. A Heckman two-step selection model was estimated for each market and the variables considered are household assets, household characteristics, and public goods. Results indicate that ownership/access to private assets, such as land, labor, and animal traction are positively associated with participation in all three markets. Participation and/or sales for contract production of cash crops requires a broader range of private assets such as livestock and agricultural equipment, suggesting that asset endowment may restrict participation in higher return markets.

This study contributes to the literature by identifying barriers to market entry for Bolivian potato farmers and conditional on market participation, means of stimulating sales. We also analyze marketing strategies, focusing on the factors that can explain households' ability to select the most lucrative markets or combinations of markets, bringing two new dimensions to the literature. First, our research considers the qualitative aspect of markets by examining the quality of household marketing strategies using stochastic dominance, which to our best knowledge is a novelty in the market participation literature. In addition, our research brings a more holistic approach to market studies by considering simultaneously three aspects of market participation: market entry, volume sold, and market choices, which should better enlighten our understanding of how market participation can leads to poverty alleviation.

Data Description and Study Area

In 2006-7, 389 Bolivian farmers living in Tiraque department, Cochabamba province (Figure 1) were interviewed about household demographic, agricultural activities, market participation, revenues, expenses, gender division of labor, and other factors. The latitude and longitude coordinates of each household were also recorded. The region is located in the Andes where elevation ranges from 3000 to 4200 meters above sea level. Steep mountainous terrains and arid and cold climates characterize the region. Households and communities are located on each side of a paved road connecting Cochabamba to Santa Cruz (two important cities in Bolivia). Ease of access to these communities depends on their location relative to the paved road, as transportation away from the paved road is limited and roads are of poor quality. By combining household location with GIS technology, precise measures of isolation were obtained, such as population density, travel-path distance between households and the paved road, and between households and the markets.

[Figure 1]

The region's economy depends mainly on small-scale agriculture, such as livestock, potato, beans, and cereals, where potato is the main cash and staple crop. For the purpose of this study, we consider only households who reported cultivating potatoes during the 2006-7 season[10]. Potato sales represent 79.5 percent of crop revenues and 49.5 percent of total household revenues (which includes other crops revenues, livestock revenues, wages, remittances, etc.). Total annual average household income was 10,386 Bolivianos (SD=11,517), which is equivalent to about 3250 $US, reflecting the low standard of living of these households. Of the 354 households, 317 (90 percent) reported participating in the potato market and those who did

[10] After eliminating observations with missing entries and potential outliers, our sample comprises 354 households.

sold on average 4914 kg (64 percent of their production), keeping the remainder for own consumption and seeds. Important variations in quantity sold (standard deviation of 5883) among households provide an opportunity to understand determinants of market participation and factors affecting volume sold.

[Table 1]

Potato sales occur at two local rural markets-- Tiraque and Punata--, and two distant urban markets-- Cochabamba and Santa Cruz. Average distances between households and Tiraque, Punata, Cochabamba, and Santa Cruz markets are 18, 36, 78, and 399 kilometers respectively (Figure 2). Sales at Tiraque market are the most common; 71.9 percent of selling households reported selling in this market. This is expected since the Tiraque market is the nearest, and, thus, the least costly to reach. About 40, 19, and 8 percent of households reported selling potato at Punata, Cochabamba, and Santa Cruz market respectively. Selling at multiple markets is not uncommon; 24 percent, 7 percent, and 1 percent of farmers reported selling potato at two, three, and four markets respectively (Table 1). In this study, we refer to the term *marketing strategy* as decisions households make relative to potato commercialization, such as market locations and number of markets where to sell potato. We use the term *marketing strategy* interchangeably with market choice. Combining markets where potatoes are transacted leads to 15 unique marketing strategies. Of these 15 marketing strategies, 13 were reported by our surveyed households (Table 2). Selling potato at Tiraque market is the most common marketing strategy, followed by selling at both local markets, Punata and Tiraque. The third most common marketing strategy is selling potato at the Punata market and the fourth, at the Cochabamba market.

[Figure 2]

For each potato transaction, households reported the quantity sold and the market price received. In a different section of the questionnaire, households reported in which markets they sold potatoes and transportation costs to reach these markets. Therefore, for households that sold potatoes in more than one market, it is impossible to link market prices with market locations. To get around this data limitation, we calculate a weighted average market price and an average transportation cost for each household[11]. The difference between the weighted average market price and average transportation cost is referred to as the *effective price* (table 2).

[Table 2]

By examining the correspondence between effective prices and marketing strategies, we notice that the apparently most remunerative marketing strategies are infrequently selected. Households obtained an average effective price of 140 Bolivianos (Bs)/100 kg (SD=29). The marketing strategy with the highest average effective price (190 Bs) involves combined sales in Tiraque and Santa Cruz. However, only one household employed this marketing strategy. The marketing strategy with the lowest effective price (120 Bs) is selling potato at the four markets. Farmers choosing --Cochabamba/Santa Cruz-- and --Punata/Tiraque/Santa Cruz-- as marketing strategies also received effective prices well above average, but again these marketing strategies were infrequently selected (table 2).

The most profitable marketing strategies always include sales at one or both distant market. However, the infrequency with which these strategies were selected lets one believe that some factors restrict participation in these markets. Likely factors include transaction costs, liquidity constraints, high opportunity costs of time, and low marketable surplus. Therefore, we

[11] The weighted market price is the market price weighted by the quantity sold. For example if household A sold 100 kg of potatoes at 150 Bs/100 kg and 200 kg of potatoes at 140 Bs/100 kg, the weighted market price for this household is (150 Bs + 2*140 Bs)/3 = 143.33 Bs/100kg. Household A reported selling potatoes in Punata and Cochabamba markets with transportation costs of 4 and 6 Bs to reach each market respectively. Thus, the average transportation cost for this household is 5 Bs and the effective price (143.33 Bs – 5 Bs), 138.33 Bs.

propose to assess determinants of market choices since price received is crucial for poverty alleviation.

Conceptual framework

Our theoretical model is based on expected utility maximization derived from consumption of potatoes (C_P), other food and non-food items (C_x), and leisure (l). Expected utility is maximized subject to three constraints: i) a cash constraint, ii) agricultural assets and technology constraint, and iii) a labor/time constraint. Households earn income from potato production (FI_p), other farm activities (FI_o), and non-farm activities (NFI). Potato production $Q_p(A_p, L_p, Z, I)$ is a function of agricultural assets(A_p) and labor (L_p) devoted to potato production, household characteristics (Z), and access to liquidity (I). Households decide whether to participate in the potato market, and those who do decide how much and where to sell. Potato market participation decisions depend on household productive capacity in relation to consumption needs and the nature of its production portfolio, which is partly determined by household-specific transaction costs (Omamo, 1998). Farmers with high transaction costs might opt for a more diversified production portfolio, leading to no or little marketable surplus. Households with low transaction costs are expected to achieve higher expected utility through specialization in potato production and a higher degree of market orientation. Transaction costs comprise fixed and proportional transaction costs and vary with household economic isolation (Renkow *et al*., 2004).

The choices households face are represented below. Households maximize expected utility:

$$Max\ EU\ (C_p, C_x, l) \qquad (1)$$

The maximization is subject to a cash constraint:

$$[Q_p (A_p, L_p, Z, I) - C_p]*P^E{}_P + FI_o + NFI - C_x*Pc_x - \tau \geq 0, \quad (2)$$

an agricultural asset allocation constraint:

$$A_p + A_o, \leq A \quad (3)$$

and a household labor constraint:

$$L_p + L_o + L_{NF} + l \leq \text{L} \quad (4)$$

The first constraint (equation 2) insures that revenues are equal to or greater than expenses. For households that sell potato (*M=1*) $P^E{}_P$ represents the effective price of potato, which is transaction specific (but for simplicity subscripts are omitted), and corresponds to the market price ($P^M{}_P$) minus proportional transaction costs (PTC) (equation 5).

$$P^E{}_P = P^M{}_P - PTC \qquad if\ M = 1 \quad (5)$$

$$P^E{}_P = P_a \qquad if\ M = 0 \quad (6)$$

For autarkic farmers (*M=0*) the price of potato is internally determined such that the autarkic price (P_a) is the shadow price at which household demand equals household supply (equation 6). τ, the last term in equation 2, is a tax equivalent capturing fixed transaction costs which reduces household income (Renkow *et al.*, 2004) and utility.

The second constraint (equation 3) stipulates that productive assets devoted to potato production (A_p) and other farm activities (A_o) should not excess total household productive assets (A). The third constraint (equation 4) indicates that labor devoted to potato production (L_p), other farming activities (L_o), non-farm activities (L_{NF}), and leisure (l) must be equal or smaller to total household labor (L)[12].

The decision to participate in the market is made by comparing the utility obtained from selling in the market to utility from self-sufficiency. Once the decision to enter the market is

[12] We assume there is no labor market for farming activities, which closely represents the reality in the study area.

made, households decide on the quantity and markets based on expected utility maximization and the constraints they face. Marketing strategy decision is made by comparing the utility derived from each alternative. Households with high fixed transaction costs might prefer to sell in local markets where the costs of doing business are lower. However, as quantity sold increases fixed transaction costs can be spread over larger volumes (Renkow *et al.*, 2004), increasing expected utility associated with sales in distant markets.

Empirical Specification

In order to address our research questions three equations are estimated, which requires two steps (equation 7). The first equation explains the decision of whether to participate in the market (y_1); the second equation describes volume sold (y_2), conditional on market participation; and the third equation depicts market choice, where the dependent variable (y_3) is a binary variable distinguishing between employment of an optimal versus suboptimal marketing strategy.

$$y_1 = f(x_1, x_2, x_3, x_4, x_5, x_6 | \gamma) + \mu_1 \qquad \mu_1 \sim N(0,1) \tag{7.a}$$

$$y^*_2 = f(x_2, x_3, x_4, x_5, x_6 | \beta) + \mu_2 \qquad \mu_2 \sim N(0,\sigma) \tag{7.b}$$

$$y_3 = f(y_2, x_1, x_2, x_5, x_6 | \beta) + \mu_3 \qquad \mu_3 \sim N(0,1) \tag{7.c}$$

Where $y^*_2 = y_2$ *if* $y_1 > 0$, otherwise y^*_2 is not observed and missing; $corr(\mu_1,\mu_2)=\rho_{12}$, $corr(\mu_1,\mu_3)=\rho_{13}$, $corr(\mu_2,\mu_3)=\rho_{23}$, *and*

$$x = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix} = \begin{pmatrix} FTC \\ PTC \\ S \\ D \\ Z \\ I \end{pmatrix}$$

x_1 is a vector representing fixed transaction costs (FTC), x_2 defines proportional transaction costs (PTC), x_3 includes factors explaining the supply side (S) (household potato production), x_4 is a vector capturing household demand for potato (D), x_5 includes household characteristics (Z), and x_6 refers to access to liquidity (I). γ, β, and δ are the parameters to be estimated.

Our first step consists of estimating the first two equations jointly using a Heckman selection model (Goetz, 1992), controlling for potential selection bias. The x_1 vector is the exclusion restrictions, insuring that the model is identified. Fixed transaction costs influence the selling production threshold, such that an increase in fixed transaction costs will raise the production threshold at which households enter the markets. However, once the decision of selling in the market is made, fixed transaction costs become irrelevant to quantity sold (de Janvry and Sadoulet, 2006). As a result, FTC are included in the first equation, but excluded from the equation explaining quantity sold. Since fixed transaction costs are not directly observable, observed exogenous factors explaining these costs are included in the FTC vector. These proxy variables are household radio ownership and population density[13]. Owning a radio can facilitate access to market price information through market price broadcastings. Living in high population density area compared to low population density area should facilitate exchange of market price information among households (Barrett, 2008). Access to market information lowers FTC, increasing the probability of market entry. In addition, access to market information can reduce perceived price risk and increase farmers' bargaining power, which will also stimulate market entry (Boughton *et al.*, 2007).

Equations y_1 and y_2 are functions of proportional transaction costs, factors affecting household supply and demand for potato, household characteristics, and access to liquidity.

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[13] Population density was obtained by combining household locations to GIS data of population density in 2000 from http://www.diva-gis.org/gdata. The raster file has cells with 30 seconds resolution (~0.8km^2).

Proportional transaction costs are captured in our model by distances (km) from the household to the paved road, distance to the Tiraque market, and distance to the Santa Cruz market[14]. (Distance to Santa Cruz is normalized by the distance to Tiraque to reduce potential collinearity issues.) The three variables reflect the costs of transporting potatoes from the field to the market and the opportunity cost of time to reach the markets. We distinguish between distance to the paved road and distance to the markets because of the limited transportation alternatives off of the paved road. Few farmers own motorized vehicles and options for transporting potato from the field to the paved are minimal; most are head-loaded or transported with beasts of burden. Once the paved road is reached, transportation opportunities become widespread. We expect economic isolation, measured by radio ownership, population density, distances to the paved road, Tiraque, and Santa Cruz markets, to increase transaction costs, negatively affecting market participation (Renkow *et al.*, 2004) and quantity sold.

Factors explaining household productive capacity (supply) are farm size (ha), value of agricultural equipment (Bs) and labor force. Labor comprises two variables: i) household members below 15 years of age, and ii) household members who are 15 years old and above. These two variables are also determinants of household demand for potato. Household characteristics include age, education, and gender of the household head, and share of household members with secondary education. Two variables are included to reflect access to liquidity: i) a dummy variable reflecting whether there is a wage earner in the household, and ii) wealth, where wealth is measured by the value of livestock owned. Access to liquidity can facilitate productive investments such as the purchase of fertilizers and enhancing productivity technology, and

[14] Due to the high correlation between distances to various markets, we employ distance to the closest and most frequently visited market (Tiraque) and the farthest market (Santa Cruz). Colinearity between distance to Tiraque and distance to Santa Cruz is lower since the two markets are located in opposite direction (see Figure 2). In order to attenuate the magnitude of the correlation between the two variables, distance to Santa Cruz is normalized by distance to Tiraque.

investment in transport, increasing marketable surplus and access to market. Summary statistics of these variables are presented in table 3.

[Table 3]

Our second step consists of estimating a Probit model to identify factors explaining whether a household adopted an optimal marketing strategy (y_3). The binary dependent variable distinguishes between selecting an optimal versus suboptimal marketing strategy. We define *optimal marketing strategies* as those that have the highest effective prices[15] with minimum variability. Stochastic dominance (SD), which involves comparing prices across marketing alternatives, is used to identify optimal strategies. SD analysis has been used in agricultural settings to analyze crop choices and in financial contexts to study portfolio alternatives. If a farmer has the choice between two risky crop alternatives, first-order stochastic dominance (FOSD) can be used to identify the alternative with the higher income while second-order stochastic dominance (SOSD) is required to identify the preferred alternative for a risk averse farmer, i.e. the alternative with the higher income and lower variability of income. Since we assume that households in our sample wish to minimize price variability because of risk aversion, we refer to the second-order stochastic dominance criterion to identify the optimal marketing strategies.

SOSD requires two assumptions regarding utility: i) positive marginal utility, and ii) decreasing marginal utility for all values of x, where x is the effective price (in Bs) of 100kg of potatoes, which is bounded by $\underline{x}$ and $\bar{x}$, the lower and upper price recorded. Under SOSD, marketing strategy 1 (MS_1) dominates marketing strategy 2 (MS_2) if:

[15] Theoretically the effective price should be calculated as: Market Price – PTC. We approximate PTC using transportation costs, as they are the only observable costs.

$$\int_{\underline{x}}^{\overline{x}} F_1(x \mid MS_1)dx \leq \int_{\underline{x}}^{\overline{x}} F_2(x \mid MS_2)dx \quad \textit{for all x in} \;\; [\underline{x},\overline{x}] \qquad (8)$$

This signifies (equation 8) that the area under MS_1's CDF, measured by its integral, is less than or equal to the area under MS_2's CDF for all values of x. Marketing strategies that are not dominated according to the SOSD criterion are considered to be the optimal marketing strategies. The expected utility associated with adopting an optimal marketing strategy will be greater than for all other marketing strategies.

Adoption of an optimal marketing strategy is assumed to be a function of quantity sold, fixed transaction costs, proportional transactions, household characteristics, and access to liquidity. As volume sold increases, we expect households to be more willing to travel to distant markets (Fafchamps and Hill, 2005) as fixed costs spread over a larger volume and proportional transportation costs might decrease with quantity transacted. Fixed transaction costs such as looking for price information in distant markets, might be high enough to discourage some households from joining these markets. Households with high opportunity costs of time such as those with high educational achievement might find it not worthwhile to travel to distant markets. Fafchamps and Hill find that households with children in secondary school are more likely to travel to the markets as opposed to sell at the farmgate, probably because schools are located near coffee markets; household characteristics might influence market choice. In addition, distant markets are more costly to reach meaning that liquidity-constrained households might be forced to forgo this alternative. Summary statistics of variables included in the model of optimal strategy choice are presented in Table 4.

[Table 4]

The correlation between the error structure of the second and third equations is caused by the inclusion of an endogenous regressor (y_2) in the third equation (y_3). In order to address this endogeneity issue, we use the Heckman selection model estimated in the first step to predict quantity sold (y_2). Then, we substitute quantity sold with its predicted values into y_3. This is a two-stage least-squared (2SLS) procedure that requires exclusion restrictions for identification. Potential instruments are variables that explain quantity sold but do not affect the adoption of an optimal marketing strategy except through their impact on quantity. Variables influencing potato production and consumption meet these criteria, which lead us to employ farm size, value of agricultural equipments, household members below 15 years old, and those 15 and above as instrumental variables.

Interaction terms between quantity sold and distance to Santa Cruz and between quantity sold and education of the household head are included in the equation explaining market choice. In order to cover the higher transaction costs associated with selling in distant markets, larger volumes are required, justifying the need for an interaction between quantity and distance. The interaction between quantity sold and head's education reflects the rising opportunity costs of time with education, which necessitates larger marketable surplus to make travelling to distant markets worthwhile. In addition, squared terms for distance to Tiraque and age of the household head are included to control for potential non-linearity.

Econometrics Results

Market Participation Decisions: A Heckman Selection Model

The Heckman selection model is estimated using maximum likelihood (ML) where both equations, the discrete and continuous decisions, are estimated simultaneously. A Wald test for the overall performance of the model is chi-squared distributed with a value of 108.15 and 14 degree of freedom. This corresponds to a p-value of zero, suggesting the overall significance of the variables. Marginal effects for the selection equation, i.e. for the discrete decision of whether or not to enter the potato market, and robust standard errors[16] are presented in table 5. Both fixed and proportional transactions costs have significant influences on the decision of whether or not to participate in the market. As population density increases by 1 unit (population/0.8 km^2), the probability of joining the market increases by 0.7 percent. Living in a high population density area can facilitate input access, access to transportation to markets, and reduce search costs related to market price information. A one-kilometer increase in the distance between a given household and the Tiraque market decreases the probability of market participation by 0.9 percent. Distance to the Santa Cruz market also reduces the likelihood of market entry as indicated by its significant and negative coefficient. These results suggest that geographical isolation reduces households economic opportunities associated with market participation.

Household characteristics are important determinants of market participation. Households headed by a member with secondary education are 12 percent more likely to participate in the potato market than households headed by an uneducated member. This result is consistent with Barrett (2008) who reports that insufficient education can be a barrier to market entry. However, households with a greater share of educated members are less likely to participate, suggesting that better economic opportunities might arise with education. An increase of 10 percentage points in the share of household members with a secondary education reduces market participation by two percent.

[Table 5]

A Wald test of independence between equations in the joint selection model is significant (with a p-value of 0.0239), suggesting that the estimated correlation (ρ) between equation errors

[16] Robust standard errors are reported as the model assumed homoskedastic errors, which is not appropriate since two-steps procedure results in heteroskedastic errors (Cameron and Trivedi, 2009b).

is significantly different than zero[17]. Consequently the parameter estimates for the supply equation would be biased if y_1 and y_2 were estimated separately. An F statistic for the joint test of the two instrumental variables (radio and population density) is highly significant (p-value = 0.0077 and chi-square 9.72) leading us to reject the null hypothesis of weak instruments (Cameron and Trivedi, 2009b). The marginal effects associated with the outcome equation, i.e. quantity sold, are reported with their robust standard errors in table 6.

Proportional transaction costs have a strong and negative impact on quantity of potato sold. A one-kilometer increase between the household and the Tiraque market reduces volume transacted by 249 kg, which represents a loss of 5 percent at the sample mean. Households travel on average 18 km to reach the Tiraque market. The coefficient for normalized distance to Santa Cruz also suggests welfare losses associated with isolation from markets. These results conform to previous studies reporting that quantity transacted is significantly reduced as distance to market increases (Alene *et al.*, 2008; Ouma *et al.*, 2010). Transportation-induced transaction costs influence agricultural productivity by altering relative prices, which influences input use (Stifel and Minten, 2008). These authors find that rice yield in Madagascar is negatively associated with isolation and that fertilizer and pesticide uses decrease with distance to urban centers. Jacoby and Minten (2009) also note that chemical fertilizers and modern agricultural techniques, such improved planting and weeding methods, are less likely to be used in remote areas, where remoteness is defined based on transport costs. Thus, distances to the Tiraque and Santa Cruz markets might negatively affect volume sold through the impact these variables have on productivity, and thus marketable surplus.

Our results indicate a positive association between household productive capacity and volume transacted. A one-hectare increase in farm size, from an average of 2.1 hectares, would

[17] The estimated rho coefficient is -0.669 (SE = 0.198).

increase volume sold by 868kg (about 18 percent). This finding is consistent with previous studies reporting a strong and positive association between land holdings and marketable surplus (Heltberg and Tarp, 2002; Cadot *et al.*, 2006). Conditions within the household affecting consumption demand for potatoes also have a significant impact on marketable surplus. A one-unit increase in the number of adult members (15 years old and above) reduces quantity sold by 281kg. However, the number of children within a household does not significantly influence volume sold.

Concerning the variables reflecting household characteristics, the share of household members with secondary education and headship is a significant determinant of volume sold. A 10 percentage point increase in the share of members with secondary diploma, from a 11 percent average, would lead to an additional 367kg of potato sold, suggesting a positive associated between education and volume transacted. If the proportion of male-headed households increases by 10 percentage points, from the current average of 86 percent, the average quantity sold in our sample would increase by 114kg. This result might indicate that female-headed households are more concerned about food security than male-headed households, keeping a larger share of the harvest for own consumption. Ouma *et al.* (2010) also find a significant and negative relationship between female-headed households and transacted quantities, which the authors explain by female-headed households being more negatively affected by transaction costs. Our assumption about food security is supported by the data. We find that female-headed households consumed 40.8 percent of their harvest compared to 28.5 percent for male-headed households. An F statistic indicates that the difference is statistically significant, with a p-value less than one percent level.

The variables reflecting access to liquidity are significant but the coefficient for having a wage earner in the household has the opposite sign as first expected. We find that wage earning reduces quantity sold by 1340kg per agricultural season as opposed to increasing it. After closely inspecting the data, we find that wage-earning households own and devote less land to potato production than on-wage-earning households. Households without a wage earner devoted 0.81 hectares to potato production in comparison to 0.58 hectares for those who reported wage earnings; a difference that is statistically significant at the one percent level. In addition, the value of agricultural equipment differs significantly between the two groups. Households without wage earners reported agricultural equipment valued at 2607 Bs in contrast to 898 Bs for households with wage earners. Thus, even if wage-earning households might have greater access to liquidity, these same households have fewer productive resources, which can explain the negative association between quantity sold and wage earner dummy variable. Livestock ownership has a positive impact on volume transacted. Livestock ownership can facilitate access to liquidity, making it possible for households to invest in enhanced productivity inputs, which is consistent with our expectation that access to liquidity increases quantity sold. An alternative explanation for the positive relationship between quantity sold and livestock ownership is that households with more livestock can better fertilize their potato plots, increasing production, and marketable surplus.

[Table 6]

Marketing Strategies: A Stochastic Dominance Analysis

Our first step allowed us to identify factors that impede market participation and volume transacted. Results provide avenues to stimulate market participation of small-scale farmers and use markets as a tool to alleviate poverty. Market choice, which influences the price received by farmers, is also crucial to achieve poverty reduction through market participation. The second step of this study aims to explain participation in the most lucrative markets, which leads us to resort to SOSD. Using SOSD criterion, we can identify marketing strategies that have the highest payoff with the lowest price variability, which are referred to as *optimal marketing strategy*. Of the 13 observed market combinations, two (--Tiraque/Santa Cruz--, and--Tiraque/Cochabba/Santa Cruz--) were reported by only one household making it impossible to compute their CDFs and integrals, and thus they were omitted from the SOSD analysis. An illustration of SOSD applied to the remaining 11 marketing strategies is given in Figure 3. A pairwise comparison of each marketing strategy is performed and marketing strategies that are dominated are eliminated. For example, the curve of marketing strategy 6 lays to the right of marketing strategy 13's curve, meaning that marketing strategy 6 dominates marketing strategy 13. Based on the SOSD criterion, four marketing strategies are not dominated and compose the efficient set (Figure 4)[18]: 1) Santa Cruz, 2) Cochabamba/Santa Cruz, 3) Punata/Tiraque/Cochabamba, and 4) Punata/Tiraque/Santa Cruz. Optimal marketing strategies consist of selling either at one of the urban markets or combining sales in both local markets with sales at one of the urban markets. Of 314 market participating households considered[19], only 36 of them (11 percent) selected an optimal marketing strategy. Here it is worth re-stating that optimal marketing strategies are identified based on the market price net of transportation costs only. Intangible costs[20] such search costs and opportunity costs of time are not considered when identifying the optimal marketing strategies. The second step of this study will allow us to

[18] As one will notice, the integral of the CDF for some marketing strategies is not fully covering the range of values for x. This is because these marketing strategies were infrequently selected. Consequently, we did not eliminate marketing strategies that are dominated solely by marketing strategies not covering the whole distribution of x.
[19] Three households were dropped from the previous estimations due to unavailable market information.
[20] By intangible costs we refer to costs that are not a direct out of pocket expense for the producer.

determine if these factors restrain households from selecting one of the most remunerative marketing strategies.

[Figure 3]

[Figure 4]

Selecting an optimal marketing strategy: A Probit Model

The probability of having less revenue when selecting one of the optimal marketing strategies is smaller for all possible outcomes, making us wonder why only 11 percent of the households selected an optimal strategy. Our objective is therefore to identify which factors restrict access to the most lucrative market or combination of markets. To do so, a Probit model that accounts for heteroskedasticity is estimated using ML. We employ a Wald test to compare the standard Probit, which assumes homoskedastic errors, to the heteroskedastic Probit model. The null hypothesis of constant variance is rejected with p-value of 0.0005 indicating that the heteroskedastic Probit model better fits our data than the homoskedastic model (Cameron and Trivedi, 2009b). An F statistic was also conducted to test for the joint significance of the instrumental variables (excluded variables) used to predict quantity sold. The F statistic has a p-value of 0.008 and a chi-square of 20.69, which strongly support the relevance of the exclusion variables and reject the null hypothesis of weak instruments (Cameron and Trivedi, 2009b). Marginal effects and robust standard errors of the Probit model explaining whether or not a household selected an optimal marketing strategy are reported in table 7.

[Table 7]

Quantity sold has a significant and positive impact on selecting an optimal marketing strategy. An additional 100 kg of potato sold increases the probability of selecting an optimal marketing strategy by 0.6 percent. Since all optimal marketing strategies imply sales at distant markets, this might indicate that greater volumes are required for the benefits to outweigh the higher fixed and intangible costs of traveling to distant markets. In addition, farmers selling greater volumes of potatoes might have stronger bargaining power, explaining the positive correlation between quantities sold and strategies with higher payoffs.

Fixed and proportional transaction costs significantly impact household choice of marketing strategy. Radio ownership increases the probability of selecting an optimal marketing strategy by 3.2 percent, suggesting that radio price broadcasting has a significant and positive influence on marketing decisions. The likelihood of selecting an optimal strategy increases by 0.5 percent as population density increases by one unit (population/0.8km^2). Living in a high population density might facilitate market information exchange, improving marketing outcomes. Our results are consistent with previous studies (Vakis *et al.*, 2003; Renkow *et al.*, 2004) reporting the importance of market information. Living 1 km farther from Tiraque reduces the probability of selecting an optimal marketing strategy by 6.1 percent while a one-kilometer increase in the normalized distance to Santa Cruz leads to a reduction of 6.2 percent. These results confirm our previous findings concerning the disadvantage of economic isolation.

Household characteristics have a significant influence on market choice. Male-headed households are 8.2 percent less likely to select an optimal marketing strategy than female-headed households. This is consistent with the fact that in Bolivia, negotiating and selling potato is a woman's task. Households whose head completed secondary education are 6.6 percent more likely to select an optimal marketing strategy than households whose head is uneducated. However, if the interaction term between head's education and quantity sold is omitted, primary education significantly increases the probability of selecting an optimal strategy over lack of education, while secondary education does not have a significant impact. This supports our assumption that educated heads have higher opportunity costs of time, requiring larger quantities in order to make the decision to travel to distant markets worth-while. Our results indicate that limited productive capacity and lack of education are barriers to participating in more lucrative markets. Even when accounting for potential non-linearity, the age of the household head has a positive impact on adopting an optimal marketing strategy, reflecting the benefits associated with experience. Older heads might have a larger social network, facilitating market information exchange. The share of household members with secondary education has a negative impact of the selection of an optimal strategy, suggesting that education might divert educated households away from potato production.

Last, we find that having a wage earner in the household increases the probability of selecting an optimal marketing strategy by 7.7 percent. This suggests that access to liquidity can help cover the higher transportation fees associated with reaching more distant markets and is consistent with our theoretical framework that stipulates that liquidity-constraint households might be financially unable to reach the most lucrative markets.

Conclusions and policy implications

The conceptual framework presented in this paper allowed us to analyze market participation decisions and marketing choices of Bolivian Andean potato producers. The motivation for this research is to provide avenues to alleviate poverty through promoting market entry, increasing volume sold, and facilitating access to more remunerative markets. Our first approach consisted of estimating a Heckman selection model where the goal was to identify factors limiting market participation and quantity sold. Results from the selection equation suggest that market participation is strongly influenced by transactions costs. Education also plays a role in the decision of whether to enter the market. The decision of how much to sell depends on household productive capacity, especially access to cultivable farmland, proportional transaction costs, and education.

As transaction costs are the main limiting factor for autarkic producers, interventions facilitating access to market information and improving transportation alternatives and road quality within the study area could increase market participation and raise producer welfare. For market participating households, a combined reduction in proportional transaction costs with a boost in household production capacity would have a great impact on volume sold. Since land is a limited asset, alternative means of increasing agricultural productivity should be considered, such as introducing new agricultural technology and technical assistance. Access to credit could facilitate the acquisition of agricultural equipment providing another avenue to enhance production.

The second approach considered to increase income through market participation is to facilitate participation in more remunerative markets. Stochastic dominance analysis was performed, and marketing strategies with higher incomes and lower variability were identified. These marketing strategies are referred to as optimal. Then, a probit model was estimated to identify factors explaining adoption of an optimal marketing strategy. Our results indicate that fixed and proportional transaction costs, access to liquidity, and quantity sold impact market choices, suggesting that lack of liquidity, limited productive capacity, and high transaction costs impede households from reaching more profitable markets. Credit programs, better road infrastructure, improved public transportation, and investment in market information systems could reduce the financial and time constraints to sell in distant markets, easing the adoption of more profitable marketing strategies. The last alternative that deserves consideration to raise household income through market participation is collective marketing. In addition to reducing transportation costs, collective marketing, such as agriculture cooperative, can increase producers bargaining power, price received, and household income

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Table 1: Descriptive statistics on market location and number of market where potatoes are sold

Market location	**Mean (%)**	**N**
Tiraque	71.9	228
Punata	40.4	128
Cochabamba	18.6	59
Santa Cruz	7.6	24
Number of market	**Mean (%)**	**N**
1	67.8	215
2	24.0	76
3	6.6	21
4	1.0	3

Table 2: Average effective price[a] for 100 Kg of potato in Bolivianos (Bs) per marketing strategy

	Marketing Strategies	**N**	**Mean (Bs)**	**Std Dev.**	**Min.**	**Max.**
1	Tiraque	135	139.13	27.18	75.00	213.69
2	Punata	48	137.26	31.77	75.00	196.00
3	Cochabamba	18	144.15	30.78	86.73	185.00
4	Santa Cruz	14	133.56	22.50	108.57	183.54
5	Tiraque/Punata	55	140.35	31.30	82.00	246.50
6	Tiraque/Cochabamba	14	131.24	27.42	93.50	175.50
7	Punata/Cochabamba	3	132.95	14.32	120.29	148.50
8	Tiraque/Santa Cruz	1	190.50	.	190.50	190.50
9	Cochabamba/Santa Cruz	3	172.74	33.71	149.00	211.33
10	Punata/Tiraque/Cochabamba	17	147.42	21.63	87.00	175.67
11	Punata/Tiraque/Santa Cruz	2	169.97	3.34	167.61	172.33
12	Tiraque/Cochabamba/Santa Cruz	1	142.33	.	142.33	142.33
13	Tiraque/Punata/Cochabamba/Santa Cruz	3	120.25	55.92	64.50	176.34
Average		314	139.64	28.85	64.50	246.50

a. The average effective price is the difference between the weighted average market price and average transportation cost.

Table 3: Descriptive statistics of the variables included in the Heckman selection model

	Market Participants		*Market non-participants*		*Sample*	
Variables	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**
Market Participation	1	0	0	0	0.9	0.31
Quantity sold (kg)	4914.45	5881.57	0	0	4400.8	5764.89
Population density (0.8 km^2)	15.95	6.82	11.97	7.61	15.54	7.01
Radio ownership	0.83	0.37	0.51	0.51	0.8	0.4
Distance to Tiraque market (km)	17.91	6.44	21.36	9.51	18.27	6.89
Distance to paved road (km)	1.72	1.52	1.37	1.6	1.69	1.53
Normalized Distance to Santa Cruz	27.12	22.17	27.03	15.88	27.04	16.61
HH members of 15 years old and above	3.27	1.63	3.40	1.82	3.38	1.80
HH members below 15 years old	2.43	1.71	2.22	1.87	2.25	1.86
Agricultural equipment (Bs)	1979.90	8887.16	452.38	610.45	1820.25	8423.78
Farm size (ha)	2.19	2.56	1.02	1.22	2.07	2.48
HH head gender (1.Male)	0.87	0.34	0.78	0.42	0.86	0.35
HH head education						
None	0.16	0.02	0.19	0.07	0.16	0.02
Primary	0.79	0.02	0.76	0.07	0.78	0.02
Secondary or higher	0.05	0.01	0.05	0.04	0.05	0.01
HH head age	46.88	14.69	46.68	13.82	46.86	14.59
Share of members with secondary diploma	0.11	0.18	0.14	0.20	0.11	0.18
Livestock value (Bs)	7301.74	4399.15	11929.96	8068.05	11446.22	7890.17
Dummy if there is a wage earner	0.57	0.50	0.45	0.50	0.46	0.50
Number of observations	317		37		354	

Table 4: Descriptive statistics of the variables included in the Probit model explaining marketing strategy

	Optimal MS		*Sub-optimal MS*		*Sample*	
Variables	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**
Predicted quantity sold	7530.845	2781.324	5692.647	2707.796	5915.104	2777.954
Population density (0.8 km^2)	18.000	6.031	15.641	6.909	15.927	6.844
Radio ownership	0.947	0.226	0.819	0.386	0.834	0.372
Distance to Tiraque market (km)	17.971	4.686	17.875	6.665	17.886	6.452
Distance to paved road (km)	1.582	1.406	1.741	1.535	1.722	1.519
Normalized Distance to Santa Cruz	23.554	5.621	27.585	16.816	27.097	15.935
HH head gender (1.Male)	0.947	0.226	0.862	0.345	0.873	0.334
HH head education						
None	0.079	0.044	0.170	0.023	0.159	0.021
Primary	0.895	0.050	0.772	0.025	0.787	0.023
Secondary or higher	0.026	0.026	0.058	0.014	0.054	0.013
HH head age	43.053	16.379	47.399	14.438	46.873	14.727
Share of members with secondary diploma	0.090	0.142	0.109	0.177	0.106	0.173
Livestock value (Bs)	14016.290	6754.451	11660.200	8224.965	11945.330	8088.412
Dummy if there is a wage earner	0.474	0.506	0.449	0.498	0.452	0.499
Number of observations	38[21]		276		314	

[21] The two marketing strategies reported by only one household (Tiraque/Santa Cruz, and Tiraque/Cochabba/Santa Cruz) were considered as optimal.

Table 5: Marginal effects for the discrete decision to participate in the market of the Heckman selection model

Variables	**dy/dx**	**P-values**
Population density (0.8 km^2)	0.00652	0.017
Radio ownership *	0.04982	0.185
Distance to Tiraque market (km)	-0.00906	0.042
Distance to paved road (km)	0.00546	0.643
Normalized Distance to Santa Cruz	-0.00387	0.014
HH members of 15 years old and above	0.00582	0.529
HH members below 15 years old	-0.01850	0.068
Agricultural equipment (Bs)	0.00005	0.256
Farm size (ha)	0.03574	0.246
HH head gender* (1.Male)	-0.02187	0.597
HH head education* (Base level: none)		
Primary	0.02501	0.616
Secondary or higher	0.11609	0.021
HH head age	0.00021	0.868
Share of members with secondary diploma	-0.22944	0.006
Livestock value (Bs)	0.00001	0.063
Dummy if there is a wage earner*	-0.02521	0.449

(*) dy/dx for factor levels is the discrete change from the base level.

Log pseudolikelihood = -3218.313

Table 6: Marginal effects for the continuous decision to sell potatoes of the Heckman selection model

Variables	**dy/dx**	**P-values**
Distance to Tiraque market (km)	-249.003	0
Distance to paved road (km)	-84.478	0.624
Normalized Distance to Santa Cruz	-90.543	0
HH members of 15 years old and above	-281.654	0.044
HH members below 15 years old	94.325	0.577
Agricultural equipment (Bs)	-0.027	0.273
Farm size (ha)	868.251	0.001
HH head gender* (1.Male)	1135.314	0.044
HH head education* (Base level: none)		
Primary	472.285	0.471
Secondary or higher	-1680.377	0.207
HH head age	-39.163	0.118
Share of members with secondary diploma	3671.205	0.072
Livestock value (Bs)	0.075	0.068
Dummy if there is a wage earner*	-1340.969	0.039

(*) dy/dx for factor levels is the discrete change from the base level.

Table 7: Marginal effects of the Probit model explaining marketing strategy

Variables	**dy/dx**	**P-values**
Predicted quantity sold	0.00006	0.000
Radio ownership *	0.03152	0.003
Population density (0.8 km^2)	0.00475	0.010
Distance to Tiraque market (km)	-0.06055	0.025
Distance to paved road (km)	0.00585	0.652
Normalized Distance to Santa Cruz	-0.06162	0.013
HH head gender* (1.Male)	-0.08166	0.003
HH head education* (Base level: none)		
Primary	0.01340	0.753
Secondary or higher	0.06590	0.087
HH head age	0.00242	0.012
Share of members with secondary diploma	-0.15752	0.028
Livestock value (Bs)	-0.0000003	0.822
Dummy whether there is a wage earner*	0.07739	0.020

(*) dy/dx for factor levels is the discrete change from the base level.

Log pseudolikelihood -84.22257

Figure 1: Map of Bolivia by Departments and Provinces

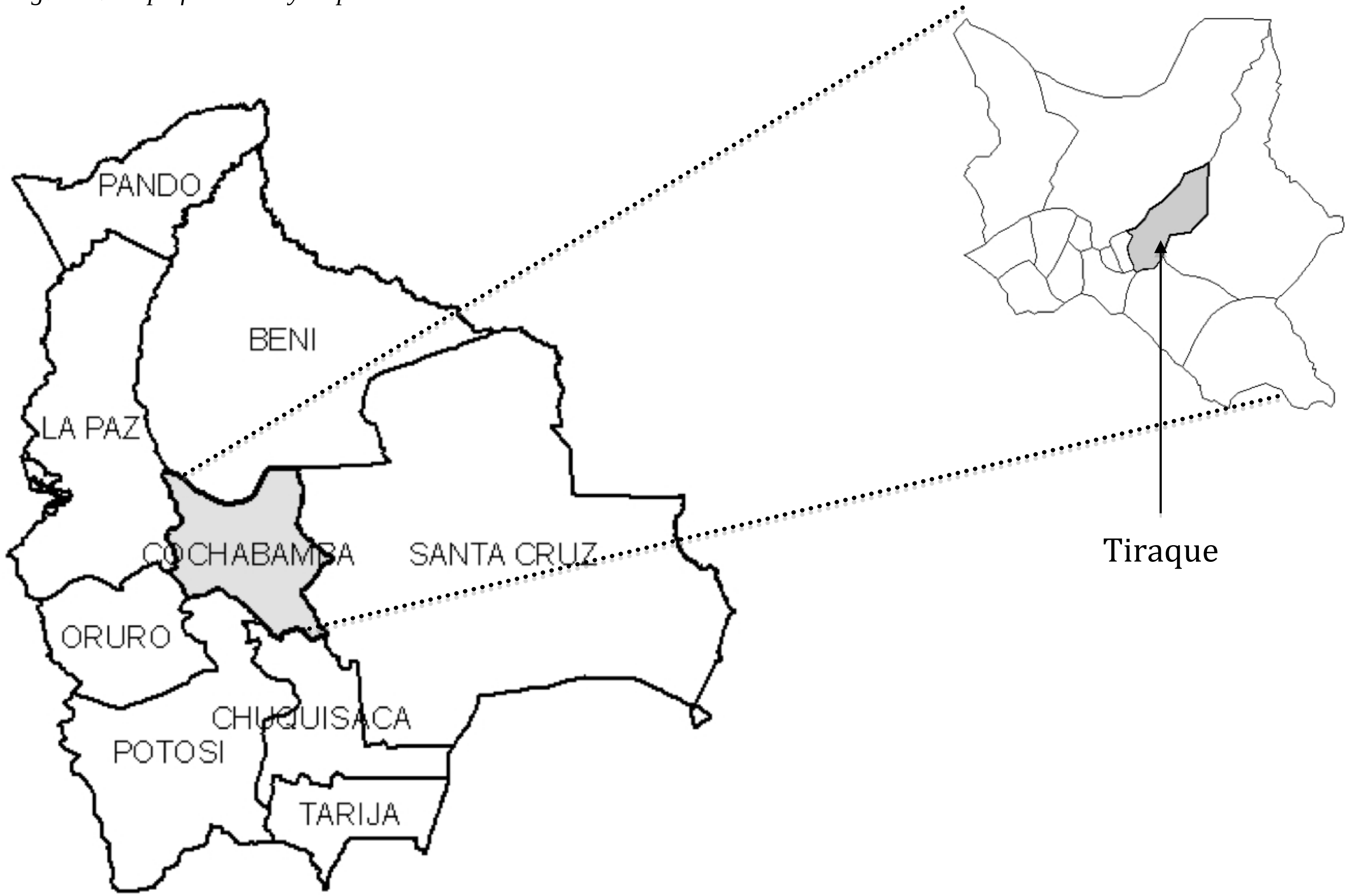


Figure 2: Study area, household location, and distances to markets

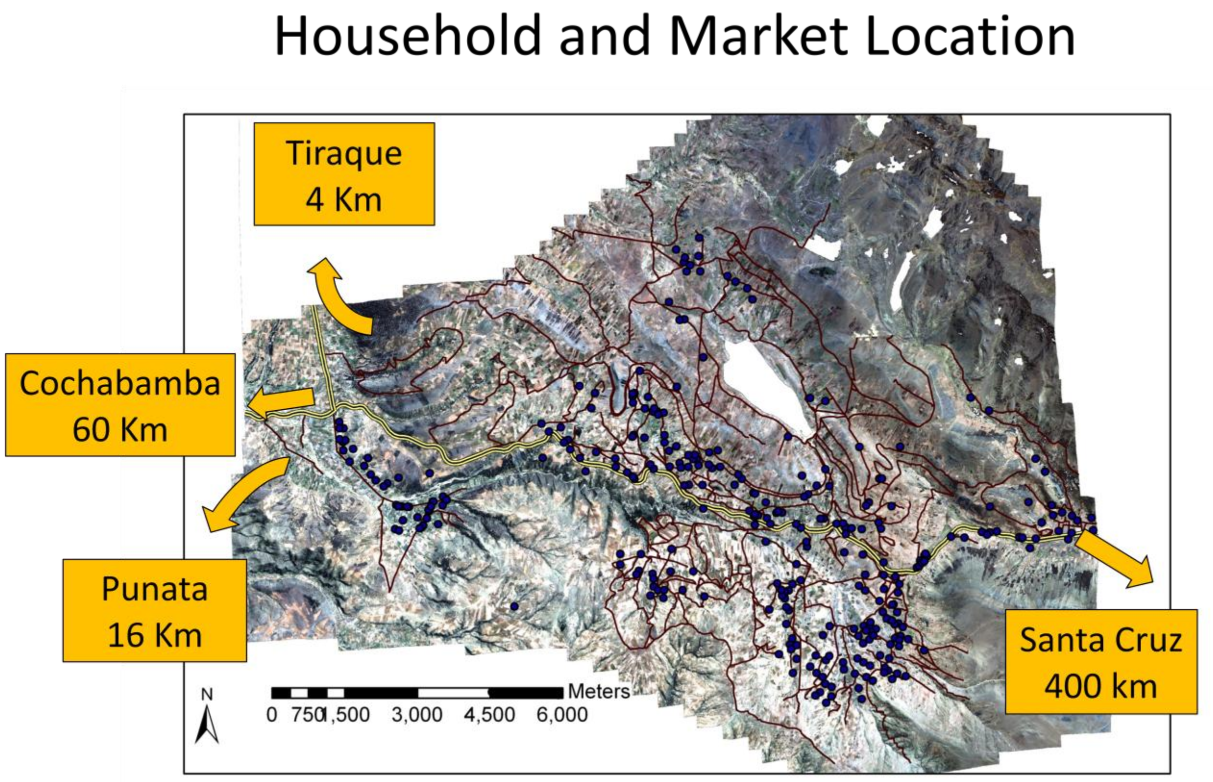


Figure 3: Second-Order Stochastic Dominance Analysis

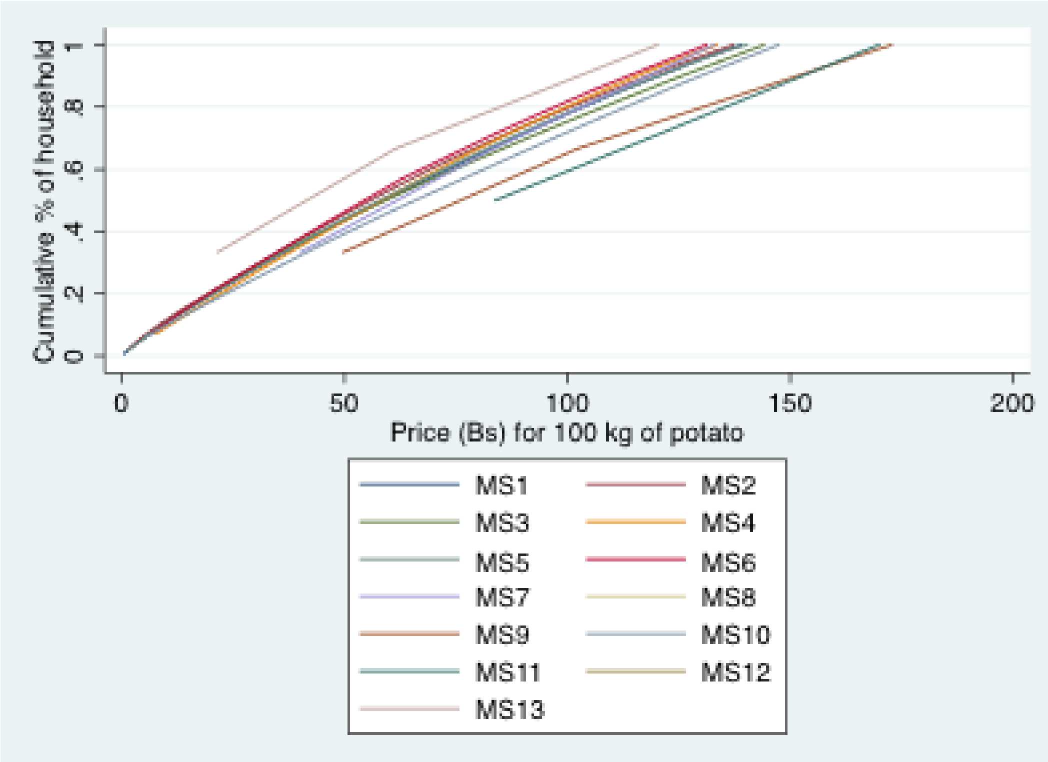
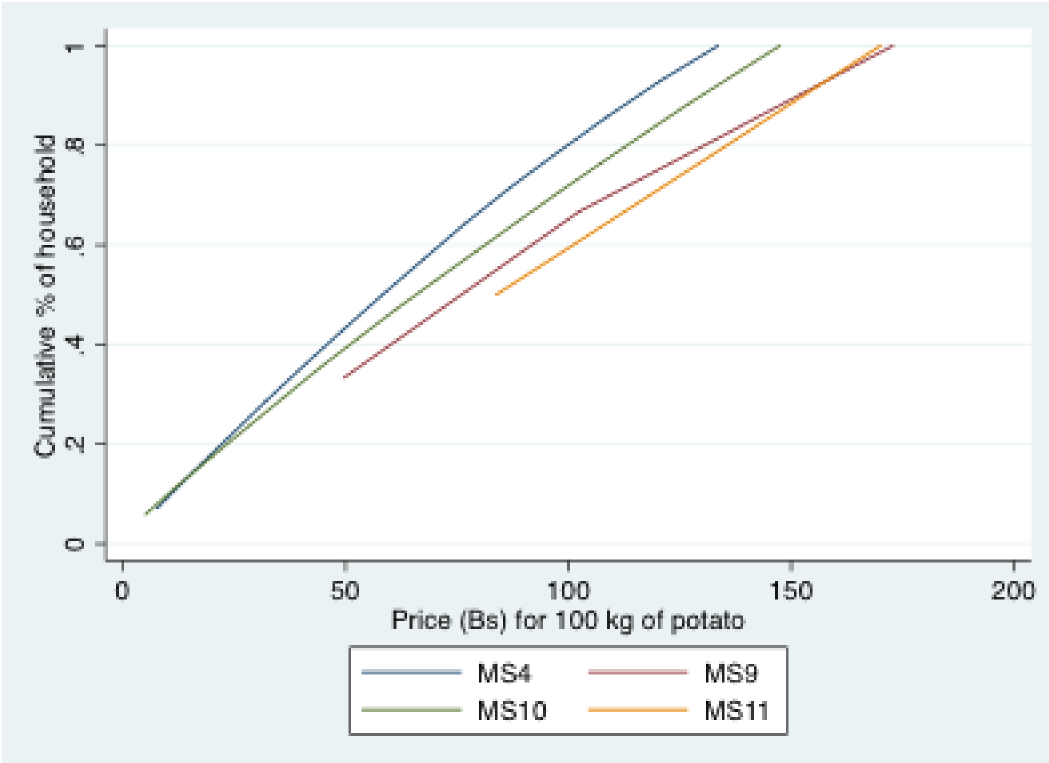


Figure 4: Second-Order Stochastic Dominance Analysis: Efficient Set



ESSAY 3: A profile of changes in well-being in Zimbabwe, 2001-2007/8, using an asset index methodology

Introduction

The decade beginning in 2000 was extremely difficult for Zimbabweans as economic and social crises contributed to widespread hardship. Economic stress grew out of trends evident during the latter years of the past millennium. Beginning in the early 1990s, the country began a process of structural adjustment that cut public sector employment, reduced government involvement in key sectors, and liberalized trade and foreign exchange markets. It was hoped that these actions would stimulate private sector growth, but into the 2000s the economy was not generating sufficient employment, and key sectors such as agriculture and mining were under-performing. A growing trade imbalance and shortage of foreign currency drove down the value of the Zimbabwean dollar, drove up food prices, and created shortages of fuel and food staples. For various reasons, the International Monetary Fund stopped budgetary support to Government in 1999 and the situation rapidly spiraled out of control. Toward the end of the 1990s, foreign investors began to abandon the country as investment risks rose.

Social tensions increased with continued inability to address the economic problems. Several food riots occurred in 1998, and general unrest grew as people became impatient with the slow pace of economic improvement. In rural areas, social conflict resulted from land invasions beginning in the late 1990s. In 2000, Government embarked on a poorly planned "fast track" land reform process that abandoned prior principles and accelerated land grabbing and the exodus of white commercial farmers. The process damaged the commercial agriculture sector, reducing availability of maize, the main food crop, and exacerbating foreign exchange problems. By mid-2007, hyper inflationary forces were consuming the economy[22]. Confidence in the Zimbabwean dollar plummeted and people increasingly turned to transactions in foreign currencies such as the US dollar, the South African Rand and the Euro.

Prospects for increased stability grew following the political agreements for power sharing reached following the 2009 national election. These agreements have increased optimism about a more stable economy and investors are gradually returning to the country. International donors are turning their focus away from short-term relief toward long-term investments to reinvigorate the economy and promote pro-poor growth. Since Independence in 1980, poverty reduction has been a focus of the Zimbabwean government, and there is widespread concern that recent economic instability has exacerbated an already precarious situation[23]. As Zimbabwe moves forward, it is important to understand conditions faced by the poor, how these conditions have changed over time, and how they vary among population sub-groups. Household asset bases, which can form the basis of subsequent income growth, have likely changed during the 2001-8 period of economic chaos, but the pattern of change and its implications for post-crisis recovery are unknown.

Part of the problem facing Zimbabwean policy-makers is insufficient information upon which to make decisions. Analysis of the impacts of the crisis on households has been hampered by lack of nationally representative household data. Periods of

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[22] The official rate of inflation at the start of 2009 was 231 million percent, but private sector economists put the percentage as high as 65 followed by 107 zeros (Pilossof, 2009).
[23] Estimates of national poverty indicate that since at least the 1990s, more than 50 percent of Zimbabweans are poor (CSO 1998; PASS 2005).

pronounced inflationary pressure lower the reliability of money-metric measures of household well-being and poverty. For example, it is now accepted wisdom that consumption expenditures are the preferred indicator of household well-being (Ravallion, 1992; Deaton, 1997) but challenges to measurement of real consumption expenditures during periods of hyper-inflation are daunting. Fortunately, alternatives to money-metric analysis exist; for example, there is a growing literature on use of asset indices to reflect longer-run household economic status (Sahn and Stifel, 2000; Filmer and Pritchett, 2001; Sahn and Stifel, 2003; Bollen *et al.*, 2007; Moser and Felton, 2007; Wall and Johnston, 2008).

This paper uses newly available data from identical nationally representative household surveys conducted in 2001 and 2007/8 to evaluate how well-being and asset positions of Zimbabwean households have changed. The objectives are to: (i) test the use of an asset index to distinguish between households of different economic status; and (ii) understand how the profile of poverty has changed during the period of crisis.

The Incomes, Consumption and Expenditure Surveys (ICES) of 2001 and 2007/8, conducted by the Central Statistical Office of Zimbabwe (CSO) produce information for national accounts and cost of living indices, and contain information on household demographics, asset ownership, schooling and health care, labor market participation, and household enterprises. A money-metric measure of well-being is constructed using consumption expenditures from the 2001 ICES and asset indices are constructed using polychoric principal components analysis (Moser and Felton, 2007; Kolenikov and Angeles, 2009) from both survey periods. The expenditure data from 2001 are used to benchmark the 2001 and 2007/8 asset indices and cutoff values from 2001 expenditures are transformed into asset index space. These cutoffs are used with the 2007/8 data, which contain good instruments only of assets, and comparisons are made between the survey periods.

We find that rural poverty and extreme poverty grew significantly over time, while in urban areas, poverty fell slightly while extreme poverty grew. The 2001-7/8 period was more favorable for female-headed than male-headed households. Asset poverty decreased for households headed by a permanent paid employee, an indication of the economic stability associated with this employment type. Increased poverty and extreme poverty in highly rural provinces is in part due to the higher prevalence of poverty amongst households of communal and resettlements workers. These households owned fewer durable goods in 2007/8 than they did in 2001, suggesting that asset selling was employed to cope with the crisis. Non-poor households living in rural areas own significantly less livestock in 2007/8 compared to 2001, another indication of coping activities.

Conceptual framework and methods

Economic analyses of poverty usually employ money-metric measures of well-being with consumption expenditures being the preferred measure for use in developing countries (Deaton, 1997). A large literature has emerged on poverty measurement using expenditures and it is now standard practice for development practitioners to create poverty profiles as a preliminary step in designing poverty-reduction interventions.

In the face of inflationary pressures such as those experienced in Zimbabwe during 2007/8, consumption expenditures are, however, practically useless. With monthly inflation rates exceeding 10,000 percent during the period, the real value of consumption expenditures will depend on exactly when the product was purchased. While CSO collects data on prices, they do so once a month and, during 2007/8, prices were changing hourly or more frequently[24]. Thus, although consumption expenditures were used as measures of household well-being by CSO in its earlier poverty analyses (CSO 1998 & 2005), they could not be used in 2007/8.

As an alternative, several studies use an asset-based methodology to rank households according to asset welfare. Filmer and Pritchett (2001), for example, use principal components analysis (PCA) applied to household asset ownership and housing characteristics to create a wealth index for Indian households. They find that the resulting wealth rankings produce coherent results and that the wealth index does a good job predicting outcomes such as child's school enrollments. Sahn and Stifel (2000) use factor analysis (FA) applied to asset data from Demographic and Health Surveys (DHS) from 11 African countries to examine differences in poverty across them and changes over time. Booysen *et al*. (2008) update the Sahn and Stifel study but use multiple correspondence analysis (MCA) instead of FA to examine changes over time in asset-based well-being for 7 African countries. Both studies find that the asset index indicates a decline in poverty, but results vary by country and type of asset: private asset portfolios seem to have improved while access to public assets declined.

The asset index bypasses the need to collect consumption expenditures, and overcomes liabilities associated with expenditure-based measures (Sahn and Stifel, 2000). Use of an asset index to measure household well-being has appeal. Although asset indices do not directly reflect consumption expenditures, they bear a close

[24] Zimbabweans recall that in retail outlets prices of products would change between the time a queue was entered and the sale point was reached.

correspondence to long-term economic status (Filmer and Pritchett, 2001). In the short-run, expenditures will vary (although, generally, not by as much as income) in response to shocks to income (Siegel and Alwang, 1999; Alwang *et al.*, 2001), so that the asset index will evolve slowly while measured consumption may fluctuate substantially (Filmer and Pritchett, 2001; Sahn and Stifel, 2003; Booysen *et al.*, 2008). While emergency and other programs need information on transitory poverty, longer-term development policy should focus on conditions faced by the chronic poor, which are more likely to be reflected by an asset index. In addition to its intrinsic appeal, an asset approach has instrumental value to risk management and long-term growth. As households face short-run fluctuations, strong asset bases help them to manage risks. Recovery from shocks can be quicker if the household has a stronger asset base. Public investments to stimulate income and well-being growth can be more effective when household asset bases are strong (Jalan and Ravallion, 1998; Siegel and Alwang, 1999)

A key challenge to employing an asset index is how to combine information on household ownership of various assets into a single index. If price information were available, assets could be valued, but such an approach would have to overcome problems of different asset qualities and ages, and how to value publicly provided or non-priced assets. Researchers have overcome this problem by using techniques noted above (PCA, FA or MCA). These methods allow the data to determine the appropriate weights of individual assets so that an asset index score can be computed for each household as defined by equation 1.

$$AI_i = \sum_{j=1}^{n} w_j a_{ij} \tag{1}$$

AI_i represents the asset index score of household i, a_{ij} is the ownership status of asset j, and w_j's are the weights to be estimated. Methods to estimate asset weights employ different assumptions and some are more appropriate in certain contexts.

The main assumption behind PCA is that there is an underlying (unobserved) latent variable assumed to represent long-term well-being (AI_i), which can be observed through ownership of various assets (a_{ij}). The set of assets normally includes durable goods, housing characteristics, and access to public services and are expressed in the form of dummy variables (categorical variables are split into multiple binary variables). Weights are estimated according to the correlation structure amongst assets and correspond to the eigenvectors of the first principal component of the covariance matrix. "The first eigenvector is the vector that minimizes the squared distances from the observations to a line going through various dimensions." (Moser and Felton, 2007, p.3) PCA is similar to Ordinary Least Squared (OLS), but the residuals are minimized relative to all variables in PCA as opposed to only the dependent variable in the OLS case (Moser and Felton, 2007). Issues reported in the literature regarding PCA are: i) PCA is more suited for continuous variables (Adbi and Valentin, 2007), and ii) in the presence of ordinal data the assumption that variables must be positively correlated with the latent variable and each other and normally distributed is violated. In fact, when an ordinal variable is split into a set of dummy variables, the negative correlation between the variables brings noise to the estimation process (Kolenikov and Angeles, 2009).

FA and PCA are similar, but slightly different assumptions underpin them. In FA, the covariance matrix is assumed to represent a smaller number of unobserved common factors. Consequently, additional assumptions to define the model structure are needed

(Sahn and Stifel, 2003). Household rankings are similar across FA and PCA methods, with Filmer and Pritchett (2001) reporting a Spearman rank correlation coefficient of 0.988. MCA is a generalization of PCA that allows analysis of correlations between categorical variables as opposed to continuous variables. Categorical variables are split into multiple binary variables as for PCA. When derived with MCA, the estimated weights of these binary variables are consistent with the natural ranking of the categorical variable. However, this is not always true when the weights are obtained through PCA. (Booysen *et al.*, 2008).

Kolenikov and Angeles (2009) and Moser and Felton (2007) argue that in the presence of categorical variables, polychoric PCA is a more appropriate estimation method than those cited above. In polychoric PCA, weights are obtained by estimating a polychoric correlation matrix and not a covariance matrix. "Similar in spirit to an ordered probit regression, polychoric PCA uses maximum likelihood to calculate how that continuous variable would have to be split up in order to produce the observed data." (Moser and Felton, 2007, p.5). Polychoric PCA can accommodate categorical and continuous variables, which neither of the above methods can do. Before deriving weights using Polychoric PCA, categorical variables are ranked according to their natural ordering as opposed to being split into binary variables as with PCA, FA, and MCA. By ordering the data, the researcher brings additional information, improving efficiency. Correctly addressing the correlation structure between variables within a same category eliminates spurious correlation and produces more accurate estimates. Another advantage of the polychoric PCA is that it provides coefficients weights for both owning and not owning a given asset, allowing the index to reflect asymmetries in the ownership/well-being relationship.

When examining the correspondence between consumption expenditures and asset indices, Sahn and Stifel (2003) remind us that imperfect correlations between measures are expected. Filmer and Pritchett (2001) report Spearman rank correlation coefficients between asset indices and consumption expenditures of 0.43 for Pakistan, 0.56 for Indonesia, and 0.64 for Nepal. Rank correlations between the two measures are as low as 0.31 for Jamaica and as high as 0.71 for Peru and South America in Sahn and Stifel (2003). Booysen *et al.* (2008) find that their asset index, constructed using the Ghanaian Living Standards survey, has a correlation coefficient and Spearman rank correlation coefficient with household per capita expenditures of 0.421 and 0.493, respectively.

Methods

We build on the asset index approach discussed above and combine it with a more traditional approach to a poverty profile. We employ polychoric PCA to compute asset weights and compute an asset index score for each household. We examine how the 2001 asset index corresponds to consumption expenditures as an indicator of economic status using the Spearman rank correlation and variations in poverty profiles by welfare measures. We use the asset index to create poverty profiles and examine changes in poverty patterns over the two survey periods.

Data

The ICES contains information on socio-demographic characteristics, incomes, economic activities, and expenditures on more than 230 food and 330 non-food items. Estimated values of consumption of own-account production items, gifts, transfers, and in-kind payments are also recorded in the survey. We use the fourth ICES, implemented from January through December 2001 containing 12,192 rural and 6,490 urban observations. We compare this with the fifth ICES, conducted from July 2007 through June 2008 containing 11,221 rural and 2,973 urban observations. Questionnaires are virtually identical, but the consumption expenditure data from the fifth ICES are not suitable for use due to the hyperinflation that characterized the period.

The consumption portions of the 2001 questionnaire permit construction of a consistent measure of consumption expenditures. The measure includes the value of all goods and services consumed or destroyed by use in the previous month. The value of all foods, other non-durable goods and directly consumed services, such as education and health, are included, as are flows of consumption values from ownership of durable assets, the value of housing services for owner-occupied housing[25], and imputed values of gifts, transfers and remittances. Two poverty lines were constructed using the 2001 data: the food poverty line (FPL) and the total poverty line (TPL). The FPL corresponds to the food basket that provides at minimum cost household food energy needs. The TPL accounts for non-food basic needs (CSO, 1998). Households with real per capita

[25] The value of owner-occupied housing was computed using a hedonic regression for houses for which rents were reported. Predicted rents from separate regressions were used to impute housing values for each survey year. Details are available from the authors.

consumption expenditures[26] below the TPL are considered poor and those below the FPL are extremely poor.

Construction of the well-being index

We refer to our asset index as a "well-being index" to highlight the notion that the asset index reflects broader dimensions than asset ownership and wealth. It reflects a money-metric dimension of poverty, through ownership of private assets, and a well-being dimension, through access to quasi-public assets such as sanitation. We employ polychoric PCA during estimation.

Thirteen variables were selected and grouped under three categories: i) durable goods, ii) housing characteristics, and iii) access to sanitation. Including a large number of variables helps prevent the likelihood of numerous households being concentrated on the same index value (Rutstein and Johnson, 2004). This "clumping" problem is common for households with similar patterns of low asset ownership and low access to public services (Howe *et al.*, 2008).

Durable goods reported in Filmer and Pritchett (2001) and also available in our data are radio, television, refrigerator, bicycle, automobile, and sewing machine. Since "consumer durables make the highest contribution towards the ability of a wealth index to proxy consumption expenditure" (Howe *et al.*, 2009, p.874), we add stove and heater ownership to this list. Variables for housing characteristics are comprised of dwelling type, main cooking fuel source, and access to electricity. Type of toilet facility and main source of drinking and cooking water comprise the sanitation component of the index. Access to these public services helps distinguish between households of different

[26] Prices were deflated using province-specific price indexes from CSO.

economic status. Moreover, access to public services increases economic opportunities by lowering the costs of searching for these services, allowing greater productivity of labor (Rutstein and Johnson, 2004). Table 1 presents asset ownership profiles for urban and rural households for both survey years; table 2 shows profiles for quasi-public assets.

[Table 1]

Of the 13 variables, four are ordinal: dwelling type (five categories), cooking fuel (three categories), toilet facility (four categories), and main drinking source (six categories). The remaining variables are binary and can be viewed as ordinal variables with only two categories. An important assumption behind polychoric PCA is that each categorical variable has a natural ordering. For example, the natural ordering for *toilet facility* is that a "flush toilet" is superior to a "Blair toilet", which is superior to a "pit toilet", which is superior to having no toilet facilities. "Flush toilet" is coded[27] as 4 and "no toilet" as 1[28]. For binary variables, 0 (1) indicates lack of ownership (ownership) of the asset.

[Table 2]

Preliminary investigations indicate that rural poverty would be overstated and urban poverty underestimated (based on 2001 consumption poverty rates) if a unique index is estimated for both locations. The propensity of the asset index to rank rural households poorer than per capita expenditures is discussed in Filmer and Pritchett (2001) and Booysen *et al.* (2008). Filmer and Pritchett (2001) conduct their analysis using either only rural data, or when pooling data, control for location. Booysen *et al.* (2008) do not differentiate between rural and urban locations during the estimation of the

[27] Ranking of the categorical variables are reported in parentheses in tables 1 and 2.
[28] The results are invariant to the starting point for the coding (that is, results are identical if "no toilet" is coded as 0 or 1).

asset index and find poverty incidence of 0.7 percent in urban Zimbabwe and 58.4 percent in rural areas. Based on consumption expenditures, CSO estimates of incidence of household poverty are 73.0 percent in rural areas and 33.8 percent in urban areas ('Poverty in Zimbabwe 2001,' 2007)

This misrepresentation of urban-rural poverty differences is due to a different structural relationship between asset ownership and household well-being across the areas. Since the relationship between wealth and access to assets and public services differs between rural/urban locations in Zimbabwe (tables 1 and 2), weights should be location-specific (Montgomery *et al.*, 2000; Sahn and Stifel, 2003; Jamal, 2005; Lindelow, 2006; Vyas and Kumaranayake, 2006; Stifel and Christianensen, 2007).

The estimated coefficients are derived by pooling the 2001 and 2007/8 survey data[29]. As a result, the weights are averages over 2001-2007/8 and are referred to as "pooled weights" instead of "baseline" or "year-specific weights" (Booysen *et al.*, 2008). Even if polychoric PCA is estimated using assets that have relatively stable values over time, using average weights minimizes differences in poverty prevalence that can arise from changes in relative prices. To confirm our strategy, we re-estimated the index using the 2001 and 2007/8 data separately and obtained baseline weights for each. The weights are similar when estimating the coefficients separately for both years, with a coefficient of correlation of r = 0.999, validating our strategy.

Asset index scores

While difficult to interpret, the polychoric PCA coefficients (Table 3) can be seen as indicating the benefit of owning or the penalty of not owing a particular asset or

[29] The following studies used pooled data: (Stifel *et al.*, 1999; Sahn and Stifel, 2000; Moser and Felton, 2007)

owning an asset of inferior quality. A positive (negative) coefficient reflects higher (lower) relationship between asset ownership status and household well-being. For example, owning a television in a rural area makes a positive contribution of 0.5468 to the well-being index score while not owning a television reduces its value by 0.0587. In rural areas, having access to a Blair toilet has a positive impact on the asset index while in urban areas such access reduces the asset index value. Differences in estimated weights by rural/urban location show that the correspondence between wealth and access to public service differs with urbanity, supporting our choice of separate indices.

[Table 3]

The household asset index is computed by summing over all assets the product of asset weight and household ownership status for the given asset (equation 1). The asset index is a relative measure of poverty that ranks households according to their poverty status and can be used to assess poverty changes over time (Booysen *et al.*, 2008). Interpretation must be made relative to other households in the sample. To improve our understanding of the source of changes, we decompose the asset index into its three sub-components

$$AI_i = \sum_{j=1}^{n} w_j a_{ij} = \sum_{j=1}^{l} w_j DG_{i,j} + \sum_{l+1}^{m} w_l HC_{i,l} + \sum_{m+1}^{n} w_m AS_{i,m} \qquad (2)$$

where $DG_{i,j}$ represents the durable goods component, $HC_{i,l}$ the housing characteristics component, and $AS_{i,m}$ the access to sanitation component for household *i*. Each component is computed by summing over the assets within a respective category the weight multiplied by the household ownership status of that asset. Summing the three components give us back the original asset index score.

We then examine changes in each sub-component of the asset index for different population sub-group between 2001 and 2007/8, in order to better explain how structural changes in the Zimbabwe economy have affected well-being.

$$\begin{aligned} AI_{2001} &= DG_{2001} + HC_{2001} + AS_{2001} \\ AI_{2007} &= DG_{2007} + HC_{2007} + AS_{2007} \\ \Delta AI_{2001,2007} &= \Delta DG_{2001,2007} + \Delta HC_{2001,2007} + \Delta AS_{2001,2007} \end{aligned} \quad (3)$$

F statistics (e.g. $\Delta DG_{2001,2007} \rightarrow Fstatistic(1, n_{2001} + n_{2007} - 1)$) are used to test whether changes in each of the three components of the asset index are statistically significant.

Establishing poverty lines

In contrast to other studies employing an asset index approach, we use the 2001 poverty incidences established based on consumption expenditures to define our asset poverty lines. The cumulative distribution functions (CDF) of the 2001 asset index are calculated for rural/urban households separately. Then the CDFs are used as reference points to identify the asset index values that preserve the percentage of households considered poor and severely poor in 2001 using the consumption expenditures per capita metric and the official Zimbabwe poverty lines. These asset index cut-off values (Table 4) represent the asset poverty lines for 2001 and 2007.

[Table 4]

Analysis of the asset index

We analyze the correspondence between our well-being index and per capita expenditures in two ways: (i) using the Spearman rank correlation coefficient, and (ii) briefly comparing a profile of poverty in 2001 using the two measures. Using the 2001 ICES, the Spearman rank correlation coefficient between the two welfare measures is

0.4172 for rural areas and 0.3610 for urban areas. Spearman tests for independence between the measures are strongly rejected (p-values = 0.0000). While imperfect correlations are consistent with expectations, these correlations are within ranges reported in previous studies (Sahn and Stifel, 2000; Filmer and Pritchett, 2001; Batana, 2008; Booysen *et al.*, 2008; Baschieri and Falkingham, 2009).

In the 2001 ICES, over 75 percent of households (82 percent of rural and 44 of urban) are consistently ranked as poor using per capita expenditures with the official poverty lines and the well-being index with the calibrated asset index cutoffs. We exploit differences in predicted poverty profiles as a check on the ability of the well-being index to identify the poor. We find a fairly consistent pattern; differences are highlighted below.

Use of the asset index leads to a lower predicted prevalence of poverty amongst rural male-headed households compared to when using consumption expenditures. Rural female-headed households are less likely to appear poor using per capita expenditure versus the asset index (table 7)[30]. Differences in gender-related poverty by measure could reflect women's spending preferences towards food and schooling versus durable goods. The 2001 ICES indicate that female-headed households devoted a statistically significant greater fraction of their expenditures on food (55.5 percent versus 49.1 percent) and schooling (1.13 percent versus 1.02 percent) than male-headed households. Male-headed households spent a slightly but significantly higher fraction of their income on durable goods (0.08 percent versus 0.16 percent).

The education level of household heads is highly correlated with household poverty status regardless of the methods and rural/urban location (table 7). Households

[30] The same trend is found in urban areas but the differences are not statistically significant.

with uneducated heads are the most likely to be poor while better-educated households are least likely to suffer from poverty. However, for households headed by an uneducated member, the predicted asset poverty is significantly higher than predicted consumption expenditure poverty in rural areas. Decomposing the asset index score into its three components reveals that households headed by an uneducated member own fewer durable goods, have housing of lower quality, and have access to fewer public services compared to households headed by member who completed primary school. For households whose head completed post-secondary education, predicted asset poverty is significantly lower than predicted consumption expenditure poverty in rural and urban locations. The durable goods component of the asset index is much larger for households headed by a member who completed post-secondary than those headed by a member with secondary education. Educated households have more assets (Bird and Shepherd, 2003) and the well-being contribution of these assets might not be reflected in the expenditures data. The comparison of predicted asset and consumption poverty by household head education suggests that the asset methodology might better capture the low (high) standard of living associated with the low (high) educational achievement of the head than consumption expenditures. This is because the lack of durable good ownerships, poor housing quality, and limited sanitation of households headed by an uneducated member might not be fully reflected in the consumption expenditures measure, where food expenditures represent the largest share. The standard of living of households headed by a highly educated member is likely to be understated, as consumption expenditures might not fully capture the higher quality of durable goods, housing, and access to sanitation of this sub-group.

In rural areas, the relative poverty positioning by employment sector of the household head is the same for each of the methods. Households headed by a permanent paid employee are the least likely to be poor while households of communal and resettlement workers the most likely to be poor (table 7). However, predicted poverty amongst rural households headed by a permanent paid employee is about 11 percent lower when using the asset index methodology compared to the consumption expenditures metric. These households have a much larger score for the durable goods component of the asset index than any other households whose head is employed in an alternative sector suggesting that the asset methodology might better capture the higher purchasing power (and thus wealth) of permanent employees over other types of employment than consumption expenditures. In urban areas, predicted poverty with both methods is the lowest among households headed by a permanent paid employee. Households headed by casual employee have significant lower scores for durable goods, housing characteristics, and access to sanitation than households headed by an own-account worker.

Difference in household size between rural poor and non-poor is much smaller under the asset index method; rural non-poor households have on average 4.30 members and rural poor, 4.76 members. This compares to 3.03 and 5.23 members using the expenditure metric (table 8). Larger households tend to have more working members than smaller households, facilitating asset accumulation. For this reason, large households appear wealthier under an asset base measure than under a per capita consumption expenditure measure; however these assets have to be shared amongst more members—a process of “asset shallowing” (Moser and Felton, 2007).

General conclusions about the well-being index

While households considered poor differ slightly between an asset base and a per capita expenditure methodology, the poverty profile analysis showed that the asset index has good ability to distinguish between households of different socio-economic status. Our results show, in accordance with Filmer and Scott (2008), that an asset base measure can be more appropriate to identify the permanently poor based on its ability to capture the longer-term welfare and permanent income concept. Assets are accumulated over time and last longer while expenditures provide a snapshot of the households' standard of living. Measurement errors and recall biases are likely to be less using an index approach improving its ability to correctly identify the chronic poor (Moser and Felton, 2007). Last, when making inter-temporal comparison of poverty, the asset index might be superior to consumption expenditures due to issues such as survey design changes and suspect consumer price indices (Sahn and Stifel, 2000; Sahn and Stifel, 2003).

Inter-temporal and rural-urban poverty changes in Zimbabwe, 2001 and 2007/2008

Urban/rural inequalities widened substantially in Zimbabwe between 2001-07/8. The predicted incidence of rural poverty and extreme poverty increased significantly from 72.7 percent to 76.3 percent and from 41.5 percent to 46.2 percent, respectively (table 5). In particular, rural poor and severely poor households have significant lower average scores for durable goods and housing characteristics in the latter years. The index scores associated with access to sanitation dropped for rural poor households and remained very low for extremely poor households. Urban household asset poverty decreased from 31.9 percent to 26.7 percent while extreme poverty increased from 9.6 percent to 11.9 percent (table 5), changes that are both statistically significant at the 5 percent level. In 2007/8, index scores of poor and severely urban households are significantly greater for durable goods but lower for housing characteristics and access sanitation.

[Table 5]

Geographical spread of poverty

Predicted poverty and extreme poverty decreased significantly in the highly urbanized provinces of Bulawayo and Midlands (table 6) suggesting a positive relationship between urbanization and poverty reduction. Decomposing the well-being index into its three sub-components indicates stable ownership of durable goods, better access to sanitation, and higher quality housing for the average poor household living in Bulawayo in 2007/8. In the Midlands, the overall population, poor, and severely poor own significantly more durable goods, live in housing of higher quality, and have access to better public services in the latter years.

[Table 6]

Contrary to other urbanized regions, extreme poverty increased significantly in Harare, from 9.6 percent to 18.0 percent, while poverty stayed relatively stable. Exacerbation of extreme poverty in Harare can be explained by the influx of rural poor households moving to Harare looking for new opportunities (Dekker and Kinsey, 2011). A coping strategy reported by poor households in Harare consists of moving into cheaper accommodations (Brown and Funk, 2010), consistent with our findings. The average severely poor households in Harare live in housing of lower quality in 2007/8. These same households have poorer sanitation access in the latter years.

Poverty and household head characteristics

In rural areas, the poverty prevalence increased significantly for male-headed households but stayed stable for their female counterparts (table 7). In urban areas, poverty decreased significantly for both male- and female-headed households but the magnitude of the change is greater for female-headed households, resulting in lower poverty prevalence amongst female-headed households in 2007/8. Female-headed households spend more on human capital (as shown with the 2001 ICES) and those able to do so invest more in productive assets than male-headed households (Bird and Shepherd, 2003), making it possible for them to escape poverty. Our results are in line with the notion that investment decisions relative to the type of capital (human versus physical) influence the household asset accumulation path over time (Moser and Felton, 2007) and way out of poverty.

[Table 7]

We observe a large increase in urban and rural poverty among households whose head completed post-secondary education (table 7). The worsening of the living conditions of professionals in Zimbabwe can be explained in part by the deterioration in employment opportunities and poor wages associated with the economic crisis. Between January and April 2007 approximately 4500 teachers resigned due to inadequate compensation. While some left the country to teach in South Africa, others have taken work during the Zimbabwean schooling holidays in South Africa in sectors such as construction and agriculture in order to supplement their poor wages. The health care sector in Zimbabwe is believed to have lost up to 80 percent of its health professionals such as doctors, nurses, pharmacists, and therapists, many of whom have migrated to other countries (Moyo and Besada, October 18, 2008). Chikanda (2007) reported that 68 percent of public sector health professionals in Zimbabwe have difficulty living on their salaries and more than three-quarters agree that additional employment is needed for public health sector professionals to make ends meet. Meager salaries earned by the most educated is one of the reasons for the brain drain and explain why those who stayed in the country are on average poorer in 2007/8 than in 2001. Urban households headed by a member who achieved post-secondary own significantly fewer durable goods in 2007/8 providing evidence that some households sold assets to maintain prior standards of living.

In urban areas, households headed by a member who completed primary or secondary education are not as poor on average in 2007/8 while change in well-being is not statistically significant for households headed by a member without formal education. This supports the association between failure to recover following shocks and the lack of education of the household head reported in Bird and Shepherd (2003) .

Poverty and household characteristics

The decline in the dependency ratio of rural poor households comes with a significant increase in household size and dependency ratios of poor urban households (table 8). These changes in household composition are consistent with migration of children living in rural areas to Harare in search of better economic opportunities (Dekker and Kinsey, 2011). The increase in family size of urban poor households could indicate desperate rural households crowding in with relatives. Household members who are not immediate family members (parents, sons, and daughters) made up 10.7 percent of urban poor households in 2001 compared to 13.3 percent in 2007/8, an increment that is statistically significant.

[Table 8]

Poverty and employment sector of the household head

Poverty decreased for households headed by permanent paid employees (table 7). This result is likely attributable to the steadier earnings and greater economic stability associated with this type of employment, allowing these households to accumulate assets more easily than those whose head is employed in other sectors. In rural areas, only households whose head is a permanent paid employee significantly accumulated durable goods between 2001-7/8. In urban area, households headed by permanent paid employees, own-account workers, and other types of workers have a greater score for durable goods, which can explain in part the lower poverty prevalence amongst the former and latter group in 2007/8.

Poverty amongst households of communal and resettlements workers (the largest share of the rural population) increased modestly from 85.0 percent to 86.7 percent between 2001 and 2007/8. Decline in food production at the beginning of the 21^{st} century (Sachikonye, 2003; Brown and Funk, 2010; Richardson, November 14, 2005), which was caused by rainfall fluctuations among other factors, might partially explain the worsening of the living conditions of this already impoverish group. Poor households of communal and resettlements areas own less durable goods in 2007/8, as suggested by the significant lower index value for this component, an indication that assets selling took place in order to cope with the hardship of the economic crisis. Moreover, households of communal and resettlement workers had the lowest quality of dwellings and the poorest access to sanitation amongst all other rural households in 2001 and 2007/8. This result is consistent with a study reporting deteriorations in dwelling quality and poorer access to public services for households of communal and resettlement areas following the land reform (Sachikonye, 2003).

Changes in livestock, productive assets, and land ownership in rural Zimbabwe

In order to gain additional insights on how well-being has changed during the period of crisis in rural areas we briefly explore changes in livestock, agricultural productive assets, and land ownership. In rural areas wealth is mainly stored in livestock (Dekker and Kinsey, 2011). In 2001, non-poor households owned significantly more cattle and poultry but significantly fewer goats and donkeys than poor households. Comparing overall livestock ownership, captured by a livestock equivalent[31] measure, reveals that non-poor households are wealthier in terms of livestock assets than poor households in 2001. Non-poor households own fewer cattle and poultry in 2007/8 and as a result, the difference in livestock equivalent is no longer significant between poor and non-poor households in 2007/8 (table 9). Mutenje et al. (2008) reported that Zimbabwean households frequently sell cattle and poultry (78 percent and 93 percent) as a mean to offset HIV/AIDS related shocks, a coping strategy that could have been extended to other shocks. During periods of stress, households are mainly worried about present consumption, causing them to sell assets (Mutenje *et al.*, 2008), which could explain part of the disinvestment in livestock assets observed among non-poor households.

[Table 9]

We find a strong relationship between poverty and productive asset ownership. A greater fraction of non-poor households own a grinding, tractor, scotchcart, and wheelbarrow while plough ownership is more common among poor households

[31] The conversion factors used to generated the livestock equivalent are based on the Tropical Livestock Units and is defined as: Cattle=1, Poultry=0.05, Pigs=0.75, Sheep=Goat=0.1, and Donkey =0.5.

irrespectively of the survey year (table 9). Deterioration in productive asset ownerships is minimal between the two surveys, a reflection of the long-lasting component of these assets. Only wheelbarrow ownership declined for both, poor and non-poor households, which can be due to its shorter lifespan and frequent usage as wheelbarrows are commonly used in Zimbabwe to transport goods as well as people (for households who do not own scotchcart) (Bird and Shepherd, 2003).

Concerning land availability, non-poor households had access and owned significantly more land in 2001 compared to poor households; non-poor households owned on average 5.911 ha of land compared to 2.196 ha for poor households. However, the difference in land ownership between the two groups is no longer significant in 2007/8. In the latter years, non-poor and poor households own respectively 3.374 ha and 3.230 ha of land (table 9). In order to better explain these changes and the role of the land reform within these changes, land ownership is broken down by land use areas (table 10). In Zimbabwe, land use areas comprise four sectors, communal areas, small-scale commercial farms, large-scale commercial farms, and resettlement areas.

[Table 10]

In communal areas, non-poor and poor households own little land and land ownership between the two groups differs only slightly. If 2001, non-poor households owned two hectares while poor households owned 2.2 hectares. While the divergence appears small, an F statistic indicates that the means are statistically different at the 5 percent level. The significantly larger amount of land held by poor households reflects the negative correlation between land ownership and land quality in communal areas. In 2007/8, poor and non-poor households own significantly more land. Reduced land pressure in communal areas could be in part explained by the land redistribution that took place in large and some small-scale commercial farms following the land reform, leading some households to leave communal areas. In addition, the difference in land holdings between non-poor and poor households was no longer significant in 2007/8. Non-poor households owned 2.6 ha compared to 2.5 ha for poor households, suggesting that the benefits of land redistribution occurred more heavily amongst non-poor households in communal areas, as non-poor households owned land of higher quality.

Our data indicate a strong affect of the land reform on land holding in small-scale commercial farms. In 2001, non-poor households reported owning 29.5 hectares of land compared to only 2.4 hectares for poor households. In 2007/8, the difference in land holdings between poor and non-poor households living in small-scale commercial farms was no longer significant. Land holdings decreased by about 10 folds for non-poor households between 2001 and 2007/8 while land holdings reached 3.6 hectares for poor households in the later years. Even if the average land ownership amongst poor households increased between the two survey years, the difference is not statistically significant at the 5 percent level. This suggests that as a result of the land reform, non-poor households living on small-scale commercial farms have lost a significant amount of farmland while land holdings among the poor households stayed relatively stable.

On large-scale commercial farms, the difference in land holdings between non-poor and poor households in 2001 was striking. Non-poor households owned 7.8 hectares in contrast to 0.4 hectare for poor households. Poor households living on large-scale commercial farms appear to have benefited from the land redistribution as in the latter years their land ownership average 4.9 hectares. As a result, the difference in land holdings between non-poor and poor is no longer statistically significant in 2007/8 on large-scale commercial farms. However, it is worth noting that many people surveyed on large-scale commercial farms are workers, not owners. Thus, it is unclear how the conditions for the former might have changed.

In resettlement areas, differences in land holdings between non-poor and poor households are not statistically significant in 2001; non-poor households owned 7.5 hectares in comparison to 8.2 hectares for poor households. However in the latter years, land ownership for non-poor households decreased significantly reaching 3.5 hectares while poor households owned 6.5 hectares, a decrease that is not statistically significant. In addition, the three-hectare difference in 2007/8 between land ownership of non-poor and poor households living in resettlement areas is not statistically significant at the 5 percent level.

In conclusion, in 2001 non-poor households living on small- and large-scale commercial farms owned more land than poor households, in resettlement areas the difference in poverty status is not significant, and in communal areas (where land area and land quality are negatively correlated), non-poor households own slightly less land than poor households. In 2007/8, land ownership does not significantly differ by poverty status in the four major land use areas in Zimbabwe.

Conclusion

We confirmed that it is possible to evaluate inter-temporal changes in household well-being without consumption expenditure or income data. We employed the asset-based estimation method called polychoric PCA. We explored how poverty profiles differ between a per capita expenditures and an asset index methodology using the 2001 ICES.

We found that the asset methodology does a good job reflecting differences in economic status of different population sub-groups in Zimbabwe. Next, we examined how poverty status of household groups changed between 2001 and 2007/8. In urban areas, poverty declined but extreme poverty increased while poverty and extreme poverty worsened in rural Zimbabwe. During this period of crisis, female-headed households were found to be better able to cope than male-headed households. For the best-educated households, poverty increased significantly, a reflection of meager salaries and poor employment opportunities, and a sign that steps are needed to improve returns to education. The conditions of households of communal and resettlements workers worsened, which suggests that lack of inputs and inadequate irrigation schemes during a period of rainfall shortages may have worsened conditions in rural areas.

The index methodology shows some potential for expanded poverty analysis. Issues associated with money-metric measurements are minimized, facilitating comparison over time and over space. The data requirements are much lower than for calculating a welfare measure base on consumption expenditures, reducing significantly the costs of data collection. In the case of Zimbabwe, hyperinflationary pressures invalidated use of a more familiar consumption expenditure measure, but the asset approach allowed us to analyze changes at national and regional levels using a representative sample.

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Table 1: Private asset ownership and housing characteristics by region and year, Zimbabwe, 2001 and 2007/8

	Rural		Urban	
	2001 (%)	2007/8 (%)	2001 (%)	2007/8 (%)
Private Assets				
Radio	46.01*	32.39*	71.41*	66.74*
Television	8.93	9.69	51.76*	64.64*
Refrigerator	2.68	2.93	31.55*	38.11*
Stove	3.42*	5.30*	75.98*	81.75*
Heater	1.14	1.37	18.94	18.99
Bicycle	22.01	20.96	19.71	19.78
Automobile	1.78*	1.19*	9.35	9.52
Sewing machine	12.55*	8.78*	22.74	20.67
Dwelling				
(1) Traditional	40.98	40.89	0.29	0.17
(2) Mixed	41.93*	44.77*	0.26*	1.36*
(3) Detached	9.03*	7.51*	56.34	55.57
(4) Semi-detached	7.25*	5.79*	30.90	29.93
(5)Flat/Townhouse/Other	0.82	1.04	12.21	12.97
Cooking fuel				
(3) Electric or gas	3.21*	4.00*	76.80	77.23
(1) Wood or coal	95.74	95.78	16.40*	22.60*
(2) Paraffin or other	1.05*	0.22*	6.81*	0.17*
Electricity				
Yes	11.22*	14.88*	88.62	85.38

*Signifies that means are statistically different at the 5 percent significance level between 2001 and 2007/8. The numbers in parentheses represent the ranking of the categorical variables. The lower values indicate assets of inferior wealth and the higher values, assets of superior wealth.

Table 2: Access to public assets in percent by region and year, Zimbabwe, 2001 and 2007/8

Access to sanitation	**Rural** 2001 (%)	**Rural** 2007/8 (%)	**Urban** 2001 (%)	**Urban** 2007/8 (%)
Toilet				
(4) Flush	4.37	4.44	95.89*	94.06*
(3) Blair toilet	44.13*	33.66*	2.70*	3.83*
(2) Pit latrine	9.79*	20.34*	1.31	1.15
(1) None/Other toilet	41.71	41.56	0.10*	0.96*
Water source				
(6) Piped inside house	2.67*	1.92*	28.60*	39.20*
(5) Piped outside house	3.38*	5.45*	65.99*	53.05*
(4) Communal tap	14.60*	8.60*	4.28*	1.30*
(3) Protected well/borehole	53.30	53.50	1.03*	5.49*
(2) Unprotected well	18.05*	21.44*	0.02*	0.95*
(1)River/Stream/Dam/Other	8.00*	9.09*	0.09	0.01

*Signifies that means are statistically different at the 5 percent significance level between 2001 and 2007/8. The numbers in parentheses represent the ordering of categorical type variables. The lower values indicate assets of inferior wealth and the higher values, assets of superior wealth.

Table 3: Asset weights derived by the estimation of polychloric PCA

Variables	Ownership categories	Coefficients*	
		Urban	**Rural**
Sewing machine	0. Does not own	-0.079893	-0.03718
	1. Owns	0.287255	0.300102
Radio	0. Does not own	-0.293667	-0.14937
	1. Owns	0.132854	0.229856
Television	0. Does not own	-0.308231	-0.058686
	1. Owns	0.212941	0.54683
Refrigerator	0. Does not own	-0.188687	-0.025587
	1. Owns	0.344108	0.771322
Electricity	0. Does not own	-0.574323	-0.076337
	1. Owns	0.087143	0.492228
Stove	0. Does not own	-0.489797	-0.03623
	1. Owns	0.127949	0.724175
Heater	0. Does not own	-0.101389	-0.014251
	1. Owns	0.427467	0.840712
Bicycle	0. Does not own	-0.030808	-0.041766
	1. Owns	0.123605	0.149778
Automobile	0. Does not own	-0.046104	-0.012248
	1. Owns	0.430598	0.635568
Cooking fuel	1. Wood or coal	-0.471522	-0.033376
	2. Paraffin or other	-0.266563	0.562339
	3. Electric or gas	0.132061	0.70619
Toilet	1. None/Other toilet	-0.761072	-0.252315
	2. Pit latrine	-0.609389	-0.006853
	3. Blair toilet	-0.490716	0.203804
	4. Flush	0.029736	0.558111
Water source	1. River, Stream, Dam, and Other	-0.761072	-0.400362
	2. Unprotected well	-0.609389	-0.202286
	3. Protected well/borehole	-0.490716	0.028661
	4. Communal tap	0.029736	0.251146
	5. Piped outside house	-0.761072	0.365047
	6. Piped inside house	-0.609389	0.505227
Dwelling	1. Traditional	-0.215779	-0.239509
	2. Mixed	-0.174083	0.08647
	3. Detached	-0.051835	0.303562
	4. Semi-detached	0.063938	0.444758

* Positive coefficients reflect high standard of living and negative coefficients, low standard of living.

Table 4: Well-being index values below which households are considered asset poor and asset severely poor

Asset poverty lines	Urban	Rural
Poor	-0.4447	0.3004
Severely Poor	-2.1544	-0.3997

Table 5: Household prevalence (%) of poverty by region, and year, Zimbabwe, 2001 and 2007/8

	2001		2007/8	
	Poverty (%)	Extreme poverty (%)	Poverty (%)	Extreme poverty (%)
Rural	72.7	41.5	76.3**	46.2**
Urban	31.9	9.6	26.7**	11.9**
Total	59.8	31.4	57.9**	33.4**

** Means are statistically different at the 5 percent level between 2001 and 2007/8

Table 6: Household prevalence (%) of poverty by province, welfare measure, and year, Zimbabwe, 2001 and 2007/8

	2001				2007/8	
	Consumption expenditures		**Asset index**		**Asset index**	
Provinces	Poverty (%)	Extreme poverty (%)	Poverty (%)	Extreme poverty (%)	Poverty (%)	Extreme poverty (%)
Bulawayo	31.8	9.1	16.2*	1.0*	8.0**	0.0**
Manicaland	72.5	45.1	65.9*	30.7*	65.8	33.3
Mashonaland Central	63.7	25.5	67.4*	33.1*	64.2	30.5
Mashonaland East	66.9	37.6	69.6*	30.8*	69.6	32.9
Mashonaland West	61.4	27.6	56.8*	28.5	60.3**	30
Matabeleland North	74.6	50.7	76.2	59.3*	81.3**	63.2**
Matabeleland South	66.7	38.4	70.3*	39.5	75.5**	51.5**
Midlands	57.8	29.7	68.5*	43.5*	61.7**	34.1**
Masvingo	71.1	40.6	73.1	46.8*	80.3**	58.5**
Harare	28.2	7.7	29.1	9.6*	28.6	18.0**

* Means are statistically different at the 5 percent level between predicted consumption expenditures and asset poverty in 2001.
** Means are statistically different at the 5 percent level between 2001 and 2007/8

Table 7: Household poverty prevalence (%) by household headship, welfare measure, region, and year, Zimbabwe, 2001 and 2007/8

	Rural			Urban		
	2001		**2007/8**	**2001**		**2007/8**
Household head characteristics	Consumption expenditures	Asset index	Asset index	Consumption expenditures	Asset index	Asset index
Gender						
Male	71.1	67.0*	72.5**	32.2	31.1	27.8**
Female	75.3	81.4*	82.6	33	34.4	24.1**
Education						
No education	82.4	90.5*	89.8	62.4	54	46.3
Primary Education	78.4	76.1*	80.6**	40.5	39.7	32.8**
Secondary Education	65	66.2	69.8**	32.2	32.9	28.3**
Post-secondary Education	19.8	12.9*	26.1**	9.5	6.8*	13.9**
Employment sector						
Permanent paid employee	47.5	36.7*	29.1**	24.7	26.9*	19.4**
Casual/temporary employee	58.4	63.1*	45.0**	37.5	47.6*	44
Communal/resettlement worker	82.6	85.1*	87.6**	33.5	13.1	32.1
Own-account worker/employer	65	63.8*	68	42.8	34.3*	34
Others	69.8	75.9	80.1	40.9	34.0*	24.6**

* Means are statistically different at the 5 percent level between predicted consumption expenditures and asset poverty in 2001.
** Means are statistically different at the 5 percent level between 2001 and 2007/8

Table 8: Household composition by poverty status, welfare measure, region, and year, Zimbabwe, 2001 and 2007/8

	2001				2007/8	
	Consumption expenditures		**Asset index**		**Asst index**	
	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor
Rural						
Household size	3.03	5.23	4.30*	4.76*	4.37	4.80
Dependency ratio	0.31	0.53	0.37*	0.51*	0.37	0.49**
Head age	42.01	47.18	42.22	47.11	41.93	46.78
Urban						
Household size	3.52	5.02	4.35*	3.27*	4.25	3.52**
Dependency ratio	0.27	0.41	0.33*	0.28*	0.34	0.32**
Head age	38.54	40.73	39.83*	37.99*	40.88**	37.85

* Means are statistically different at the 5 percent level between predicted consumption expenditures and asset poverty in 2001.
** Means are statistically different at the 5 percent level between 2001 and 2007/8

Table 9: Livestock, productive assets, and land ownership per poverty status and year, rural Zimbabwe, 2001 and 2007/8

	2001		**2007/8**	
	Non-poor	Poor	Non-poor	Poor
Livestock (quantity)				
Cattle	2.142^	1.431	1.470**	1.394
Poultry	5.084^	4.467	4.240**	4.071**
Pigs	0.011	0.022	0.011	0.019
Sheep	0.014	0.022	0.035	0.018
Goats	0.388^	0.595	0.350^	0.564
Donkey	0.063^	0.088	0.035^**	0.075
Productive assets (%)				
Grinding	1.31%^	0.32%	1.18%^	0.43%
Plough	37.32%^	45.85%	34.79%^	45.17%
Tractor	1.77%^	0.29%	1.95%^	0.66%**
Scotchcart	26.42%^	19.29%	25.62%^	20.00%
Wheelbarrow	40.49%^	34.72%	33.17%^**	30.48%**
Land (ha)				
Total land available	6.101^	2.26	3.506	3.369**
Land owned (ha)	5.911^	2.196	3.374	3.230**

^ Means are statistically different at the 5 percent level between poor and non-poor households
** Means are statistically different at the 5 percent level between the 2001 and 2007/8 surveys

Table 10: Land ownership per land use areas, poverty status, and year, rural Zimbabwe, 2001 and 2007/8

	2001		**2007/8**	
Land use areas	Non-poor	Poor	Non-poor	Poor
	(Total amount of land in ha)			
Communal areas	2^	2.2	2.6**	2.5**
Small-scale commercial farms	29.5^	2.4	3.0**	3.6
Large-scale commercial farms	7.8^	0.4	5.2	4.9**
Resettlement areas	7.5	8.2	3.5**	6.5

^ Means are statistically different at the 5 percent level between poor and non-poor households
** Means are statistically different at the 5 percent level between the 2001 and 2007/8 surveys

Conclusion

This three-essay dissertation started with a study on risk mitigation and production efficiency in potato production in Bolivia. We employed a stochastic production frontier to quantify the costs of environmental and activity diversification in the form of efficiency losses and yield forgone. We found that activity diversification has the most detrimental effect on production efficiency. A decline by one percentage point in the ratio of potato to crop revenue reduces average efficiency by 6.2 percentage points, a yield loss of 1170 kg/ha of potatoes. Among the variables capturing environmental diversification, discontinuity between fields causes the largest inefficiencies. An increase in one kilometer in the field effective distance measure would decrease average efficiency by 0.61%, a loss of 117 kg/ha. We performed spatial analysis of field and household efficiency measures to assess production vulnerability to climatic shocks and the potential of environmental diversification in mitigating shocks. We found important spatial clusters of low and high efficiency at the field-level suggesting that climatic shocks significantly influence efficiency measures. Household-level efficiency measures exhibit random spatial patterns suggesting that on average households can mitigate the adverse effects of shocks through environmental diversification.

The second essay examined market participation decisions and marketing choices of potato producing households in Bolivia. The empirical specification is a two-step process where the decision of whether to participate in the market and volume transacted were estimated jointly in the first step using a Heckman selection model. Results from the selection equation suggested that market participation is strongly influenced by transactions costs. As population density increases by 1 unit (population/0.8 km^2), the probability of joining the market increases by 0.7 percent. A one-kilometer increase in the distance between a given household and the nearest market decreases the probability of market participation by 0.9 percent. Education also plays a role in the decision of whether to enter the market. Households whose head completed secondary education are 12 percent more likely to entry the market than households whose head has no formal education. The decision of how much to sell depends on household productive capacity, especially access to cultivable farmland, proportional transaction costs, and education. A one-hectare increase in farm size, from an average of 2.1 hectares, would increase volume sold by 868kg (about 18 percent), confirming the strong and positive association between land holdings and marketable surplus

The second step consisted of estimating a Probit model so that the factors explaining whether a household employs an optimal marketing strategy can be identified. We defined optimal marketing strategies as those that meet the SOSD criterion; these strategies have higher incomes and lower income variability. Our results indicated that fixed and proportional transaction costs, access to liquidity, and quantity sold have significant effects on the probability of selecting an optimal marketing strategy. Radio ownership increases the probability of selecting an optimal marketing strategy by three percent while a one-kilometer increase in the distance to the nearest market reduces it by six percent. Wage-earning households are eight percent more likely to employ an optimal marketing strategy, suggesting the importance of liquidity to cover the higher transportation costs associated with selling in the distant (more lucrative) markets. An additional 100 kg of potato sold increases the probability of selecting an optimal marketing strategy by 0.6 percent, indirectly confirming the importance of land holding in accessing better markets.

The third essay examined changes in well-being during the 2001-8 period of economic chaos in Zimbabwe. Since expenditure data were of no use in the latter survey due to the hyperinflation prevailing in the country, we resorted to the emerging literature on asset indices to construct a measure of household well-being. We employed the asset-based estimation method called polychoric PCA. We explored how poverty profiles differ when a per capita expenditures measure is used compared to an asset index using the 2001 survey of households. We found that the asset index has a great ability to capture the low standard of living associated with lack of education as well as the high standard of living related with higher educational achievement and better employment opportunity of the household head.

Next, we examined how the economic status of population sub-groups changed between 2001 and 2007/8. In urban areas, poverty declined but extreme poverty increased while poverty and extreme poverty worsened in rural Zimbabwe. During this period of crisis, female-headed households were found to be better able to cope than male-headed households. For the best-educated households, poverty increased significantly, a reflection of meager salaries and poor employment opportunities, and a sign that steps are needed to improve returns to education. The conditions of households of communal and resettlements workers worsened, which suggests that lack of inputs and inadequate irrigation schemes during a period of rainfall shortages may have worsened conditions in rural areas. The asset approach has potential to expand poverty analysis and allowed us to analyze well-being changes in Zimbabwe at national and regional levels using a representative sample.

The common theme of these three essays is poverty reduction in developing countries. The main goal of development assistance programs and the focus of policy makers in developing countries are to find effective ways to alleviate poverty. To achieve this goal there is first a need to come up with methods of measuring poverty with the existing, and often flawed, data. This dissertation provided insights of how to assess poverty and poverty changes over time without consumption expenditure data, the most widely used indicator of household well-being. The asset index methodology used in this dissertation is compatible with a wide range of surveys, including the Demographic and Health Surveys (DHS), providing avenues to expand poverty assessment and our understanding of inter-temporal poverty changes.

Once poverty is measured, interventions aiming at poverty alleviation must be pushed forward. Access to markets is key in poverty alleviation and was the focus of the second essay. Results are expected to provide policy makers with tools for more informed decision making regarding how to promote market access and improve access to better markets for semi-substance farmers. We believe that our findings could easily be extended to similar environments such as potato cultivation in Peru and Ecuador, and likely to an even broader scale. Last, providing enhanced risk management opportunities to small-scale farmers can better enable them to escape poverty. Results showed that self-managing risk through techniques such as activity and environmental diversification leads to yield forgone and welfare loss. While this is a well-known fact, it has been infrequently measured in the literature. Thus, techniques and results from the first essay could guide the implementation and management of index assurance projects in lower income countries. These projects aim at managing catastrophic weather risk and if successfully implemented, reduce household needs to self-insure, facilitating market participation and contributing to overall economic growth.