Staple Crop Diversity and Risk Mitigation- Potatoes in Bolivia

Michael J Castelhano

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Agricultural and Applied Economics

Dr. Jeffrey Alwang- Committee Chair
Dr. Nicolai V. Kuminoff- Committee Member
Dr. George W. Norton-Committee Member

08/25/08
Blacksburg, Virginia

Keywords: Bolivia, Potatoes, Selection models

Staple Crop Diversity and Risk Mitigation- Potatoes in Bolivia

Michael J Castelhano

ABSTRACT

Rural areas of most developing nations are dependent on agriculture. In the most remote areas, sometimes referred to as the 'less favored areas' (LFAs), the economic importance of agriculture is paramount. An important obstacle to development in these areas is that agriculture is at the mercy of nature, which may not be particularly friendly. These areas have remained remote due to natural shortcomings causing economic development to occur slower than more advantaged areas elsewhere. Cochabamba Department, in central Bolivia, is home to some of these LFAs. Most Cochabamban producers are located in the 'high climatic risk' (CIP-WPA) Andean highlands. Farmers in LFAs surrounding Cochabamba city produce (among other things) potatoes for market and home consumption; the potato is the main source of food and income for most residents. Previous studies and anecdotal evidence have shown that Andean potato farmers may plant upwards of 10 varieties of potatoes on small amounts of land (Brush, 92). Because of the low rates of improved crop variety adoption in many LFA's, efforts are needed to understand farmer objectives and needs with respect to variety characteristics. The goal of this study is to determine how exposure to risk factors impacts potato planting decisions through demand for potato variety characteristics. The main source of data for this project is a survey of 145 farm households implemented during the last quarter of 2007 in 3 communities of Cochabamba. These data were used to estimate an econometric model that evaluated the role of household, regional and variety characteristics in farmer decision making. Decisions about planting each variety were modeled with a Tobit framework and estimated by the Heckman method (as suggested by Cameron and Trivedi), with the impact of individual variety characteristics restricted to be the same for each variety. Several hypotheses were confirmed such as the importance of yield, though many results were different than expected. Blight tolerance was found to be negatively correlated with selection, although most farmers report taking some kind of action to decrease damage from blight. Possible explanations for this negative correlation are discussed in this paper, and strategies for overcoming these obstacles are suggested.

Staple Crop Diversity and Risk Mitigation- Potatoes in Bolivia

Contents

Tables

1.1. Introduction

Rural areas of most developing nations are dependent on agriculture. In general, the more remote the area the more marked this dependence is. In the most remote areas, sometimes referred to as the 'less favored areas' (LFAs), the economic importance of agriculture is paramount. Bad years for agriculture result in less income that farmers can spend on goods and services off the farm; good years mean more spending, and thus more money spread around the community. If the agricultural sector of these economies fails to prosper, there is nothing else to support the development of non agricultural sectors.

An important obstacle to development is that agriculture in these areas is at the mercy of nature, which may not be particularly friendly. Often these areas have remained remote due to natural shortcomings causing economic development to occur slower than more advantaged areas elsewhere. Short comings may include actual physical remoteness (constraining access to input and output markets), but can also be the result of bad weather, soil or other natural constraints that decrease productivity or increase its variability. Progress has been made over the past decades towards decreasing poverty in the developing world, but remote and less favored areas have not shared in these general gains in household well-being (Pender and Hazell 2004).

Many disadvantaged areas face heightened risk associated with agricultural production. Variable rainfalls, susceptibility to frosts, hail, diseases and pests, thin input and output markets, and seasonal labor shortages all affect the decision making process of LFA farmers. Circumstances differ by region, but the need to mitigate risks results in a tough decision making outlook. Farmers will typically accept a situation with lower output if they can guarantee a minimum level of production by doing so. Adopting such a strategy will relieve some of the risk farmers face, but may prevent them from accumulating capital and investing in their farms. When credit and insurance markets are thin or incomplete the possibility of borrowing to smooth consumption or participating in formal risk management markets may be denied. Factors that keep the area remote often prevent development of these markets.

1.2. Conditions in Bolivia

In Bolivia, many regions can be classified as 'less favored areas'. They tend to be mountainous, with low levels and high variability of rainfall. Much of the territory is high elevation and steeply sloped, and farmers cultivate broad beans, quinoa, barley, potato and other root crops using mostly traditional methods. Most farmers in these areas are Aymara or Quechua speakers, cultivating fields that their ancestors settled over a thousand years ago.

Cochabamba Department, in central Bolivia, is home to some of these LFAs. Most Cochabamban producers are located in the 'high climatic risk' (CIP-WPA) Andean highlands. Farmers in LFAs surrounding Cochabamba city produce (among other things) potatoes for market and home consumption; the potato is the main source of food and income for most residents. Bolivian potatoes tend to be produced with basic methods: low yielding varieties are common, manure is the main fertilizer and chemical pesticides are used but are often applied indiscriminately regardless of the pest or variety. Only about 25% of potato lands are irrigated. Cochabamba has a lower portion of irrigated potato production than other parts of the nation (Terrazas 1998).

Cochabamba's potato farmers face climatic risks (drought, frost and hail), disease (blight, wilt, viruses) and pests (weevils, nematodes, and moths). Input and output markets are thin in remote areas of Cochabamba, and farmers must produce much of what they wish to consume or face the risk that it will not be available in the market. Many native varieties are not readily available in markets, and are grown for home consumption. Previous studies and anecdotal evidence have shown that Andean potato farmers may plant upwards of 10 varieties of potatoes on small amounts of land (Brush, 92). One possible explanation is that farmers are using variety diversification to mitigate agricultural, climatic and market risks. Some varieties are resistant to frost, drought, disease or pests; others are planted to ensure that specific consumption desires are fulfilled. Labor market risks can also be mitigated in this way; potential labor shortages can be offset by planting varieties that mature at different times, and spreading the harvest out over a longer period, requiring fewer workers.

Research on improved potato varieties has led to beneficial adoption of improved varieties in many areas of the world. The International Potato Center (CIP) estimates that its breeding programs have increased yields by an average of at least 2.5 t/ha when adopted (Walker, 2003). Individual country analyses of these programs have returned estimates as high as 3 t/ha (Song Bofu 1996, from Walker). In conjunction with improved seed systems, the estimates reach up to 6 t/ha (Nguyen Van Uyen, 1996 from Walker). These studies come from Africa, China, Vietnam and Peru. Improved varieties like the ones in these studies (high yielding, blight resistant) are available in Bolivia (HH, Rosita/India), but have experienced low levels of adoption. The factors preventing adoption of these need to be understood, so they can be overcome if they are not related to the variety, or more appropriate varieties can be bred and made available if the barriers are related to the variety.

With constrained resources and high risks, adoption of new varieties can be difficult. Planting of improved varieties that are unfamiliar to a farmer implies a cost of time spent learning about the production and consumption characteristics of the variety; in one study it was found that farmers tend to favor new varieties that are similar to ones with which they are already familiar (Thiele et al. 1997). New varieties represent increased risk, since less exact expectations of variety performance exist. Dedicating limited resources to varieties with unknown properties may result in shortfall, in aggregate quantity or in specific characteristics. This behavior under risk could represent a significant challenge to increasing incomes of farmers. Efficient variety selection requires the researcher to understand the needs of the farmers, in both production and consumption, as well as potential barriers to adoption. After these are understood the possibility of introducing new or alternative varieties to the region can be addressed. If these considerations can be incorporated as priorities in a breeding program, the program will be more likely to produce varieties with the properties that producers desire, leading to higher rates of adoption.

This approach is meant to serve as an aid and possibly a starting point for participatory plant breeding programs (PPB). These programs, which involve farmers heavily in the selection and testing process of plant breeding organizations, have been successful in introducing new cultivars into marginal or less favored areas. Participatory breeding programs use a less centralized process for the selection of potential new cultivars. Like conventional breeding, initial materials may be generated by professional breeders, but in PPB these can be selected for testing in farmers fields (the target adoption areas) by the farmers themselves, sometimes in consultation with plant breeders and scientists. Since this will usually involve more test sites than conventional breeding, it can increase the number of cultivars being tested if farmers have differing preferences. This process can increase and/or help to preserve existing genetic diversity in a region, which is often high in LFA's, by using local cultivars to generate genetic material. PPB can also help maximize the amount of information available on specific genotype X environment interactions, by using more of one or both of those factors. The nature of mountainous Andean environments, with high levels of climatic variability, lends itself towards these programs. Individual farmers can select test cultivars specifically for their fields, according to their own preferences. The current project may be useful in identifying geographic areas and potato related risk factors that could serve as subjects for future participatory breeding programs.

1.3. Objective

Agricultural science has developed new varieties of many widely grown crops (both through breeding and more recently genetic manipulation). These varieties have addressed an array of needs, including higher output, increased input response, disease resistance and climatic tolerance. This technology has helped many farmers in developing nations increase their income. In some areas of the world, however, 'improved' varieties have seen only limited adoption, or are not associated with expected improvements (Hintze, Renkow and Sain 2003; Edmeades and Smale 2005; Dalton 2004; Smale and DeGroote 2003). This may be because science has not yet addressed specific needs of farmers in these areas, or because barriers block the farmers from adopting otherwise suitable varieties.

Because of the low rates of improved crop variety adoption in many LFA's, efforts are needed to understand farmer objectives and needs with respect to variety characteristics. The goal of this study is to determine how exposure to risk factors impacts potato planting decisions, and how specific variety characteristics affect farmer selection of those varieties. This information can help to focus agricultural research in the area of potato breeding and distribution. By understanding the characteristics that farmers choose, it will be possible to attain higher levels of adoption, and more widespread increases in yield and efficiency. This study will also evaluate the effects of household demographics, general farming decisions and practices, assets and market interactions on planting decisions. These characteristics may affect variety choice and help to identify barriers to adoption.

The primary objective of this project is to identify the role played by variety production characteristics (yield, frost tolerance, disease resistance) in the potato variety decisions of Bolivian farmers. The sub objectives to reach this goal are as follows:

1. Identify the factors relevant to farmer selection of potato varieties in the Cochabamban highlands, including:

   a. characteristics of potato varieties;

   b. characteristics of the farms and households (such as demographic make up, proximity to market, other crops grown, etc.); and

   c. risk factors such as diseases, pests, market uncertainties, and climatic problems faced by the household.

2. Measure and /or quantify the levels of expression of these characteristics for different potato types in the set of varieties that farmers in Cochabamba can choose from.

3. Relate the observed planting decisions of farmers to the characteristics of individual varieties. From this we will be able to determine the role that risk management plays in variety selection, and whether the patterns of potato diversity that exist on Cochabamban farms are due to risk mitigation or to other (probably market and consumption) preferences.

1.4 Basic Methods

The essential seed of this project comes from reading previous studies of variety selection, particularly Edmeades and Smale, 2005; Hintze, Renkow and Sain, 2003; and

Dalton, 2004. All of these studies surveyed farmers for their opinions about varieties as well as their planting decisions and household information. These beliefs, characteristics and decisions were then related using various econometric systems to evaluate the role of different characteristics in the decision making process. This project uses similar methods to determine the impact of risk factors and potato attributes on variety selection for potato farmers in the Cochabamban highlands.

The main source of data for this project is a survey of 145 farm households implemented during the last quarter of 2007. This survey was implemented with the assistance of Bolivian research staff and by partner institutions in 3 communities of Cochabamba. Farmers were surveyed on which varieties and how much of each were planted, perceptions of variety tolerance of or susceptibility to risk factors, and household and regional characteristics that may impact planting decisions. Data were also collected from extension personnel and potato scientists in Bolivia regarding their perceptions of risk factor and yield performance of different varieties.

These data were used to estimate an econometric model that evaluated the role of all these household, regional and variety characteristics in farmer decision making. Decisions about planting each variety were modeled with a Tobit framework. Estimation was carried out by the Heckman two-step method (as suggested by Cameron and Trivedi), with the impact of individual variety characteristics restricted to be the same for each variety. Several hypotheses were confirmed such as the importance of yield, though many results were different than expected.

This research was carried out with financial support from Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP)- a U.S. based research program working in several developing countries and funded by U.S. Agency for International Development. The main partner institution was the Foundation for Promotion and Research in Andean Products (Fundacion PROINPA)- a Bolivian foundation that works extensively with potato farmers and maintains the National Potato Germplasm Bank. Cooperation between these two organizations began in 2006, under SANREM's Watershed Based Natural Resource Management for Small Scale Agriculture Long Term Research Award.

The next chapter describes the conceptual framework on which this project is modeled. Ideas and theories are drawn from published research on similar projects as well as general economic theory. Chapter three presents the method, including design of the instrument and sample, implementation of the survey, and the econometric estimation techniques. The subsequent chapter discusses the data with summary statistics, describes the individual sampling regions and varieties commonly planted as well as those selected for economic analysis. Chapter five presents the results of the econometric analysis, followed by conclusions in chapter six.

2. Conceptual Framework

In this chapter the basic theory that drives the study is explained. Examples from published literature are used to provide specific ideas about how these theories work in the real world. This information is intended to help in the design of data gathering efforts as well as in the specification of an analytical framework within which to analyze the data.

2.1. Selection by variety characteristics- published literature

Published literature is an excellent source of insight into how variety characteristics and other factors affect planting and adoption decisions. By reviewing earlier projects, we can gain insight into data needed for the current study. Insight can also be gained on how to structure the economic model of the variety decision. The emphasis is on selection of variety characteristics by semi-subsistence farmers that specialize in a subsistence crop that is widespread throughout the region and may be marketed.

Dalton's 2004 paper on the economic value of rice traits explores questions of variety characteristics and variety choice. After observing experimental plots over multiple crop cycles, farmers are questioned for their willingness-to-pay for planting material of the varieties of rice they have observed. This WTP is estimated as a hedonic function of production characteristics, separately as one of consumption characteristics, and then as a pooled function of both. Variety attributes were identified while data were collected during a project of the West Africa Rice Development Association. Both magnitude and significance are different in the combined/pooled model than in individual production and consumption characteristics models. The production and consumption characteristics models each have 3 significant coefficients, while the combined model has 9. Significant variables in the production or input characteristics model include height, height squared and tillers (the number of tillers relates weed competition to weeding labor demand). On the consumer goods side, consumption characteristics were ranked by participants on a Liekert scale, with higher numbers denoting better quality. Cooking aroma, swelling and aroma squared turned up significant. When the models are combined, the number of tillers and the aroma variables no longer have statistically significant coefficients, but color, tenderness and the squared swelling and tenderness variables are significant, as is cycle length. This suggests that even if our interest lay only in one of the two, inclusion of the other would be very useful in order to achieve a full understanding of the decision process.

Another insight gained from this work is that the coefficient on yield was not found to be statistically significant (the coefficient obtained was actually negative, although the standard error was of a greater magnitude than the coefficient). Botanical characteristics of the plants (including cycle length and height) that were mentioned by farmers were seen to be significant. It seems reasonable to conclude that when observing crops in an experimental setting (or in their own fields for a single cycle) the realized yield may be seen as irrelevant, possibly because farmers don't believe that what happens in the experimental environment is the same as what will happen in their fields in the future. These botanical characteristics of the crops may be crucial to how farmers form expectations of yield potential and suitability of the variety. While the exact process may not be comparable across crops and geographic regions, some basic ideas probably are.

This gives us some ideas about what sort of characteristics farmers may be interested in. However, it is unlikely that farmers are generally able to observe new varieties in such a well-controlled setting, and to compare several different varieties side by side. This probably would not change which characteristics are important, but may change the subjective rankings of any given variety.

Hintze, Renkow and Sain's study of variety characteristics (2003) affecting adoption for maize growers in Honduras considers two different geographical areas. One is largely commercial, with modern inputs, mechanization and relatively easy access to roads and markets. The other is much more remote, has roads that are impassable for much of the year (except by four wheel drive) and uses mostly traditional methods. The commercial area has a much higher rate of adoption of modern varieties than the less favored area. To examine the decision making process, farmers are asked about their opinions about the characteristics (such as yield, drought resistance, taste and storability) of the varieties available to them. Using a system of binary variables indicating whether or not a farmer considers a particular variety to be the best available for a given characteristic and relating this to the varieties that the farmer grows they are able to identify which characteristics are persistently present in the planted varieties. In the commercial area, the comparison is between (high tech) hybrid high yielding varieties (HYVs) and (low tech) improved open pollinated varieties (OPVs), whereas in the mostly subsistence area traditional varieties (low tech) are compared to improved OPVs (high tech, relative to the other plantings in this area).

Of the 15 characteristics determined by pre-survey discussions to be important to farm decisions, yield, early maturity and drought resistance are the most significant in the commercially oriented area, Olancho. HYVs are considered to be superior to OPVs in these characteristics. In Choluteca, the subsistence oriented area, the traditional varieties are considered superior in drought resistance, taste and storability, and in guaranteed minimum yield (though not in yield). These results tell us that the main characteristic that causes farmers to adopt HYVs is their yield advantage. This is in contrast to the findings in the Dalton paper, but the other differences in the studies may explain this. According to Jones, who was affiliated with the project that originated Dalton's paper, labor is scarce in the study region, but land is not (Jones 2001). If there is enough land to grow as much rice as the household can harvest, increasing the yield of individual plants may not have a sizeable impact on household wellbeing.

Edmeades and Smale's work measures the impact of many characteristics (including household size, education, age and assets and production and consumption characteristics of individual banana varieties) on variety selection by banana farmers in remote areas of Uganda. They also incorporate farmer perceptions of variety performance under adverse conditions (risk characteristics).The variables they use come from farmer statements of expected percentage loss to banana bunch size in two different adverse scenarios (black sigatoka infection and weevil infestation). The farmer beliefs about loss differ among varieties, and the coefficient on the farmer belief is significant in the model. This article did not pursue analysis in a risk-mitigating framework, although farmer estimates of 'percentage loss' seem to be geared towards that. Instead it measures the value of risk oriented characteristics, as perceived by farmers. The analysis finds all the variety characteristics to be significant, and in the expected direction. Price and perceived cooking quality both have positive associations with variety demand, with cooking quality being of a greater magnitude. Expected percentage loss to black sigatoka disease or weevil infestation are both negatively related. No other variety characteristics are presented.

This paper differs from the others in that it attempts to measure the level of demand for a variety as a function of that variety's characteristics. The works discussed above measure the determinants of adoption or the value of different traits. Edmeades and Smale's model is the one that is closest to the current project. They seek to find the characteristics of a variety that determine its fully disseminated level of use among farmers. This variety demand function is derived by applying Kuhn-Tucker conditions to the household utility maximization problem. This function depends on both production and consumption characteristics of the varieties, as well as on output prices, price of other goods, exogenous income, and household, farm and market characteristics.

By measuring demand for varieties as a function of their characteristics, the authors approach the idea of demand for specific characteristics. This has particular implications for targeting breeding programs and for the development of new varieties. Edmeades and Smale use this framework to evaluate the impacts (through simulation) of using different varieties of banana as the host for transgenic improvement programs. That is not the goal of the current project, but the framework used to derive variety demand equations is still useful. By measuring the value of different characteristics in the determination of variety demand, we can understand how much of an impact those characteristics have in a farmer's variety planting decisions. If we are using data from varieties currently planted, this can only be realized for the characteristics that vary sufficiently across the varieties available in a given region. This does not allow us to evaluate farmer desire for currently unavailable characteristics or levels of expression, but it should not prevent us from understanding the current decision making impact of the characteristics that do vary.

2.2 Decision making under risk

In order to examine the impact of risk on decision making, we need a framework that allows us to set up the decision problem. Chambers and Quiggin's work on state contingent production (Chambers and Quiggin) provides such a framework. The decisions under consideration (which varieties to plant and how much) are made under uncertainty. When the farmer decides what varieties to plant, she does not know what conditions they will grow under (how much rain will fall, whether or not their will be weevils, etc.). Potential conditions are classified as states of the world. In a basic framework of agricultural production, states of the world could describe levels of rain, incidence of disease, or any circumstances of production that are not chosen by the farmer. The exact state of nature will be determined after the inputs to production are committed (seed is purchased and planted) by a random draw from the set of potential states. The exact production relations are determined by the realization of the state of nature. Under two different states, there may be different structures/coefficients involved in the production function; this situation leads to a key observation: inputs can have different marginal productivities in different states of nature. Potato seed having different marginal productivities under different states is embodied by the variety's resistance or tolerance to the different states. For example, seed of a variety that is susceptible to frost has a decreased marginal productivity in a state of nature where frost occurs. Producer decisions are made depending on subjective probability perceptions of the occurrence of different states of nature.

There are, of course, infinite potential states of nature. In using this state-contingent framework, we will confine concern to those states across which the production function differs. For instance, light rain may be different than heavy rain, but Xmm of rain may not incur different productivity impacts than X+1mm in a given period. Also, since these are all based on producers subjective probability measures, any state that the producer does not consider possible or likely will not be factored into the decision making process.

2.3 Analytical Model

Farmers decide what varieties of potato they are going to plant (and how much) at the beginning of each growing season. This decision is based upon expectations of the coming season, for climate, production, markets, etc. In technical terms, each household attempts to maximize their expected utility in accordance with their own subjective probability beliefs about the occurrence of different states of nature in the coming period:

1. $\max_{(v,S_m,S_f,S_v,P)} EU = \left[\sum[\pi_s * U_s]\right] + W(\alpha,\gamma)$

subject to:

2. $U_s = U(Z_s, Q_{s,} l_s \vdots HH, F, R)$ for state s

3. $Z_s = \lfloor Z_{1s}, Z_{2s}, \ldots Z_{ks} \vdots g_{ics} \rfloor$

4. $Z_{ks} = \sum_i \beta_{ik} * g_{ics}$

5. $G_{is} = G_{is}(v_i, P_s, S_f, S_h \vdots HH, F, R)$

6. $\alpha = \alpha(G_{is}, \pi_s, C)$

7. $T = l + S_f + S_m + S_v$

8. $(S_m - S_h) * w + \sum_i (p_{is} * g_{ims}) - (Q_s * p_{qs}) \geq 0$

9. $p_{is} = p(Z, S_v \vdots HH, F, R)$

10. $G_{is} = g_{ims} + g_{ics}$

The decision variables in the model are the following: v is potato seed material (v_i is seed material of variety i), S_m is labor supplied to market, S_f is household farm labor, S_v is labor supplied to the sale of potatoes and P are the controlled inputs (fertilizer, irrigation, etc.). Expected utility depends on several factors: π_s is the probability of occurrence of the sth state of nature, U_s is the value of the utility function in state s, W is a vulnerability/safety function that depends on the probability of shortfall (α, which depends on state contingent production, G_{is}, subjective probabilities, and the household's basic needs, C) and the household's preferred level of safety (γ). The utility in state s is a function of available potato characteristics, represented by Z_s, the consumption of other goods (Qs), and leisure time in state s (l_s). Potatoes available for consumption in state s are represented by g_{ics}. The characteristics of these potatoes, embodied in vector Z_s, Are k in number and are calculated by summing over the i varieties the level of each characteristic present in a variety (β_{ik}), multiplied by the amount of that variety produced for consumption in state s (g_{ics})

Utility attainment is constrained by household, farm and regional/market characteristics (HH, F, R, respectively). The amount of the kth potato characteristic available in state s is summed over the i varieties of potato produced by the household, where each variety exhibits a fixed amount (B_{ik}) of each characteristic per unit over the quantity produced in state s (G_{is}). Production of variety i in state s is determined by the seed used (v_i), inputs (P_s), household labor (S_f) and hired labor (S_h), constrained by household, farm and regional characteristics. The household splits its total time endowment (T) between leisure, farm labor, labor for potato vending and marketed labor. Earned wages less paid wages, plus potatoes of variety i sold in state s (g_{ims}) to realize the relevant state/variety profit (p_{is}), less market goods (Q_s) purchased at state s prices (p_{qs}) will be greater than or equal to zero. The gains of marketing variety i in state s are a function of variety characteristics and time supplied to potato marketing as made possible by household, farm and regional realities.

The vulnerability/safety function (W) is meant to act like a safety first protocol. If the household believes that a potential choice or plan has a risk of shortfall (α) greater than their comfort level (γ) this will act as a penalty function and decrease the expected utility of such a choice (making the household more likely to choose a plan with a lower risk of shortfall). If the household is confident that their risk of shortfall is below the maximum comfort level, this can be null or add a bonus to the expected utility of that particular plan.

Variety choice can have a large impact on the production function. As observed above, it is possible for inputs to have different marginal productivities in different states of nature. The main input we are concerned with in this project is potato seed material. If two varieties of potato seed have different marginal productivities under different states, the choice between the two effects both the level of production in each state and the probability of shortfall.

To derive the input demand functions relating to each variety of potato seed, we use the first order conditions of the maximization problem. This gives us

10. $V_i^* = V_i(Z_i, P_s, T, \pi_s, w, p_{is}, p_{qs}, C, \gamma \vdots HH, F, R)$

as the determinant of variety demand. This formulation will be used in the empirical analysis. This solution is arrived at when the expected marginal utilities of the last unit of each variety are equal:

11. $E\left(\frac{\partial U}{\partial v_i}\right) = \sum_s \left(\pi_s * \frac{\partial U_s}{\partial v_i}\right) = E\left(\frac{\partial U}{\partial v_j}\right) \forall i, j$

At the solution to the household problem, the potential increase in expected utility of planting an additional unit of each chosen variety should be equal (and this should be greater than the benefit of introducing any other variety). Expected gain from any single variety can involve a combination of consumption and marketing expectations, which are of course subject to production. The expected utility of income earned from the planned sale of the last unit of each variety intended for market should be the same as the expected utility of consumption of the last unit of each variety intended for the table. This means that expectations of price for each variety, as well as marketing costs (which include transport to market and time finding a buyer/market acceptance/ease of sale), should play an important role in the consumption decisions of the household. These may be characteristics of the variety considered, but may also be impacted by geography and household particulars. Also, there may be characteristics of some varieties that we are not aware of that impact the decision (these may be highly correlated with other variety characteristics, which could cause identification problems).

This simple model gives us some direction in terms of what sort of data should be included in the estimation. However, there are some very broad categories of data that need to be considered before they are pursued. Household characteristics can be many, many things. Its easy to say that we need to account for household characteristics in the model, but we need to have a good idea of what characteristics will have an impact.

2.4 Risk preferences and diversification

A major way that household characteristics can impact choices is through risk preferences. With the variety choice question considered here this particularly applies to ideas about technology adoption and investment and its relationship with food insecurity and poverty vulnerability. Shively (1997, 2000) addresses consumption risk in relation to adoption of soil conservation measures. The technology considered (contour hedgerows among low-income farmers in the Philippines) has a high initial cost, but generate a positive benefit over time. The thesis proposed is that risk averse, food insecure farmers may find that adoption of costly (in the short run) but beneficial (in the long run) technologies create an unacceptable risk of shortfall in the immediate future. This hypothesis is tested with a dynamic programming model that suggests that many households have little motivation to adopt conservation technologies. The model maximizes utility as a function of investments in soil conservation over a fifty year planning horizon. Levels of risk aversion and land holdings are shown to be important determinants of the feasibility of adoption. Whatever risk aversion level is used, there are two ranges of farm sizes where adoption is non-optimal, those where shortfall is possible (the smallest farms) and those that can self insure against risk (the largest farms).

What this means for the current project is that food insecure households may not have the assets available that allow them to feel secure while incurring short term costs that increase their chances for long term success. Adoption decisions may be constrained by the need to supply basic needs in the immediate future. In potato cropping, this concern for basic needs may have an effect on seed potato production (which, like investments in soil conservation structures represents a very real short term cost). It may also discourage specialization in one variety or in one crop. Farmers in high risk areas may avoid specialization, even if it might bring income benefits, because diversification may reduce the perceived probability of crop failure or disaster. Diversification will lead to reduced risk exposure particularly if varieties are chosen so that there is at least one with a high level of productivity in each state of nature that the household believes is likely to occur. We can expect that this desire to diversify will be inversely related to the household's capacity to bear risk. The capacity to bear risk should be positively associated with the household's endowment of assets. This includes cash, things that can be directly exchanged for cash (livestock, grain or consumer goods, for example) as well as human capital (skills, ingenuity, education) that can be marketed for profit. Access to formal and informal credit and insurance markets also increase capacity to bear risk.

Variety diversification in the California peach industry is explored in Tadesse and Blank's 2003 article. In this case, variety diversity is seen primarily as an attempt to lower income variability by spreading out the timing of crop maturation and harvest. If two varieties of peach blossom, develop and are picked at different times this may reduce the proportion of the crop that is exposed to potentially disastrous climatic effects. Using ten years of data from Fresno County freestone peach orchards, Blank shows that diversification leads to results that are at least as good as the orchard's best variety and usually better when measured in terms of income (higher) and income variability (lower).

These results suggest that variety diversification can be considered as a strategy adopted by high risk farmers. But diversity may cost more, especially if varieties have different growing needs or marketing circumstances, to farmers who are not exposed to high risk or who cannot offset the types of risk they are exposed to by varietal diversification. For example, potato farmers in high earthquake risk zones may not benefit from variety diversification, as different varieties of potato are not believed to have different reactions to earthquakes. If risk is being offset, the varieties chosen must have a low positive or a negative correlation of yield or income. For temporal risks such, as labor shortages or early or late season climatic risk, we would expect to see differences in planting or harvest times. For non-temporal risks, we should see differences in the way that varieties chosen by a single agent react to risk factors (frost or disease resistance for example). Market risks may also be offset by diversity, if the market price for different varieties is relatively uncorrelated, or if varieties are harvested at different times in situations where market price varies noticeably with time of year. If high levels of diversity exist without any of these other risk factors, diversity may represent consumption preferences (for subsistence or semi-subsistence farming households and/or where markets for some varieties may be incomplete/thin) or inefficiency. Diversity may also be linked with higher marketing costs. If we think that ease of marketing is a major benefit of specialization, we would see less specialization in situations where other marketing costs are too great for this to make a real difference, such as in remote areas.

We would expect remoteness from markets also to lend some benefit to diversity due to inability to purchase alternatives to what is grown on the farm.

Arguments for diversity similar to those already presented could apply to other kinds of diversity as well. Diversity across crops or across activities (including crop agriculture and livestock or non-agricultural work, for example) will have the same benefits attributed to diversity across varieties, if the correlation of income is relatively low. While diversifying into different crops or into non-crop activities offers much more divergent sources of income (lower correlation of returns) than diversification across varieties, it is just as likely to involve more investment, whether in learning about other crops, traveling to a non-agricultural job, or purchasing equipment for craft making or small business.

2.5 Summary

The main interest of this project lies in the role of variety characteristics and how they impact potato variety choice. The above discussion highlights the fact that these characteristics may be very important, and that accounting for as many of them as possible is key to getting a better understanding of the role of each. Adoption costs, market access, risk related behavior, household makeup and variety characteristics all have important roles in ideas of variety choice. All of these issues will contribute to an understanding of the problem at hand. These ideas give us a direction in which to move to pursue this project. They helped determine the information and data needed to move forward. Once this information and data is collected, these ideas will also serve as a guide for creating an empirical model.

3. Methods

This chapter discusses the methods used for collection and analysis of data. The first half addresses data collection, including instrument design and implementation. Next, the econometric analysis is discussed, and the formal empirical model is presented.

3.1 Survey Design

The main source of information for this study is a survey implemented by research staff and by PROINPA personnel in Bolivia. This instrument [see appendix] was used to collect data on the types of potatoes that farmers plant, the area planted to each variety, and farmer perceptions of performance of specific varieties. These perceptions are of those they plant currently and any other they have recently planted but have discontinued. It also collected information on household characteristics, including demographic information, management practices and data on market interactions. The field survey took place in November 2007, while the author was in Bolivia for this purpose. Data from 145 households were collected.

Survey questions were originally conceived at Virginia Tech, translated into Spanish and sent to colleagues at PROINPA for review. These questions were based on previous SANREM surveys as well as concepts and theory from published literature as discussed in the prior chapter. After seeing the questions and making agreed upon modifications, PROINPA personnel drafted the initial layout of the questionnaire. This, along with a translation and other required paperwork was submitted to the Virginia Tech Institutional Review Board for approval (IRB # 07-517, approved Nov. 2007). Format revisions were made by the author in Bolivia after further consultation with PROINPA staff and with enumerators. The layout was similar to that used by PROINPA for their recent household survey of the Tiraque area. Aside from being the easiest way to accomplish the layout, this also made the new surveys familiar to the enumerators, who had all worked on the Tiraque household survey.

3.2 Sample

Three regions were selected in Cochabamba Department. Fundacion PROINPA has local offices in Tiraque, Colomi and Morochata, and has regular contact with at least some farmers there. All of these regions are inhabited mainly by smallholder farmers, most of whom depend on potatoes for a living. A target of 150 households had been established before the research trip, based on the number of observations contained in previously published studies and on statistical considerations. Colomi and Morochata were selected to comprise the bulk of the sample, with a target of about 60 households surveyed in each. Tiraque, where PROINPA had recently fielded a household survey, was known to be fairly homogeneous in terms of potato grower's strategy. Because time was limited, it seemed reasonable to set that target lower, at 30 households.

Villages in each region had to be selected before hand, as it would be necessary to obtain permission from village leaders before surveying. PROINPA extension personnel helped to identify areas that were representative of the region and contacted local leaders in each area. Little information was available beforehand about these areas. As a result, primary criteria for sample selection were geographic; more and less remote villages were selected from each major sampling region based on distance to local market and road access. One village in Tiraque (Cebada Jich'ana), two in Colomi (Candelaria, with good road access, and Sora Sora, farther away from the central town and reachable over a steep and rocky dirt road) and two in Morochata (Piusilla, near the main road and Toldo Moko, about forty minutes further down a side road by truck) were selected for the surveys.

Some surveying was done at group meetings. This allowed for less down-time while surveying households. Meetings attended included a farmer organization meeting in Primera Candelaria (Colomi, about 20 surveys) and one in Morochata (about six surveys). An irrigation channel construction site in Morochata also served as a location where many surveys were completed. Workers were interviewed on their lunch break, and at the end of the day. Market participants in Colomi were also interviewed. Whenever these groups were encountered, efforts were made to find and interview members of the community not belonging to the group. This was done by searching for willing participants in these areas while the meetings or workday were ongoing.

Researchers were also careful in checking that they were not ‘doubling up’ any single households by interviewing a husband in one location and a wife or adult child in another.

Because of the small size of the communities, along with the lack of prior information about specific households, sampling strategies were limited. An attempt was made to obtain as complete a picture of each community visited as possible. In general this involved surveying adults from as many households in each village as were available and willing. It should be noted that some respondents may not have been the primary agricultural decision maker, though most were suitably familiar with the household’s agricultural plan. All household members participate in seeding the potato plots, so familiarity with potato plantings is reasonable to expect.

The research team surveyed almost all potato farmers encountered. A few declined, and two were excluded by accident due to miscommunication with enumerators (this problem was corrected swiftly). One community functionally declined to allow enumerators to survey in the village. The leader who could have given permission was not available during the period that researchers were in the region; colleagues in Bolivia suggested that this constituted a non-confrontational way of saying no.

3.3 Additional Data Collection

In addition to the survey data, information was collected from PROINPA technicians in Bolivia. This information serves as a backup to farmer data, and to confirm survey results. Information was collected from one technician (Julio Gabril) in the Cochabamba office on potato variety performance under risk exposure. This was done using a qualitative scale evaluating whether the varieties were resistant/tolerant or susceptible to each risk factor. Risk factors identified include frost, drought, hail, blight, worms, weevils nematodes, piki piki and llaja (locally known pests).

Yield estimates were also solicited from PROINPA technicians. Extension personnel filled out a form stating what they believed would be an average, good (top 5%) and poor (bottom 5%) yield for each variety that they were familiar with. These estimates were used to generate means and standard deviations of a triangular distribution. Statements were sought from extension workers with duties in each of the three regions. Forms used are reproduced in the appendix.

3.4 Missing/Unavailable data

Several categories of desired information were not obtained. Time and budget constraints had a lot to do with this. The most important of these are characteristics of the plots where farmers plant potatoes. Altitude of plot, size of plot, distance from home, distance from road/market, soil quality, etc. of each plot all may play a role in variety choice. PROINPA's recent experiences with the baseline household survey completed during the 3rd quarter of 2007 suggest that obtaining this information is more difficult than just asking farmers. Earlier surveys of Bolivian farmers encountered similar problems with knowledge of plot size (Terrazas). Follow up work after the baseline survey led PROINPA to believe that much of the info collected on plots was inaccurate. Conducting an in-depth survey of the layout and makeup of farmland in the regions was far beyond the scope of this study.

Price information on potato varieties was also desired, but in the end considered not practical to obtain. Colleagues in Bolivia have maintained that price information is hard to come by, and not necessarily all that meaningful when encountered. Colleagues also stated that price depends very much on production in the region as a whole, and is not easily predicted. Marketing practices in general do not seem to be well understood by researchers at this point in time. Focused research in this area would be of great interest, but does not exist at this time.

More specific information about variety risk performance characteristics was explored, but (like the above categories) determined to be beyond the scope of the current study to obtain. Information available on all of these topics was limited, often based on a single location or temporal period. It would have been possible to include some conjectures based on the available information, but it seemed equally likely to be distortionary as it was to be elucidating. For this reason, the analysis proceeded without this information. The result is not an ideal situation, but believed to be enlightening in many ways.

3.5 Methods- Empirical Model and Estimation

Several methods exist for estimating the relationships between variety choice, variety attributes and household characteristics in the process discussed in this project. If this were a single choice, model design would be much easier. But since households often choose several varieties, the model becomes slightly more complicated than a single choice model. The possibilities for modeling this process fall into three rough categories: 1) Demand systems, 2) Aggregated/strategy choice, 3) Binary choice. Determining which option is most suitable for our purposes involved some tradeoffs. Unified demand systems are structural models that have the potential to portray choices among multiple goods. They involve complicated, often intractable integrals and are often estimated using simulation (von Haefen, Phaneuf and Parsons, 2004). They also involve specifying the form of the utility function, from which one can derive first order conditions used in the simulation. While it is not difficult to specify a utility function that behaves according to our theoretical preconceptions, this, in conjunction with the need to use simulation becomes a process that is very complicated and not necessarily more accurate than less structural methods.

A strategy choice model would involve something like a multi-nomial logit (several possible choices, each actor chooses one), where households select (each household makes only one choice) from a group of available strategies. To formulate this it is necessary to identify the strategies. With the wide array of varieties and combinations in our data, and the lack of patterns in variety choice, this would mean aggregating varieties into types (traditional low yielding, or improved high yielding blight resistant could be two examples of these categories). This assumes that each choice aggregated into a category has identical probability of selection (Train, 2003). In practical terms, it would be saying that there is an equal probability that households will choose each variety in a given category. Since we do not have data to draw a complete picture of each variety, this is unappealing and would probably lead to bias. Also the results of this type of model would not be easily adaptable to our goal. They would help us relate household characteristics to strategy choice, but would not give us much insight into the actual variety selection question.

The binary choice model in this scenario would look at each variety separately and whether or not each farmer chose to plant that variety. These choices are commonly assumed to be independent so that choosing whether or not to plant variety i does not depend on the choices made about any other variety. This is not an ideal assumption. However, given the shortcomings and assumptions involved in the other models, it is not clear that this will be a less desirable approach. It is straightforward to implement and provides easy to interpret results. There is also some precedent in using binary choice in variety selection (Edmeades and Smale, Hintze, Renkow and Sain). Because of these factors, it was selected as the best alternative for this problem.

The first step to begin defining the empirical model is to define the choice set that farmers face when making their variety planting decisions. There are two parts to such a choice set: the varieties that farmers choose to plant, and the ones that they choose not to plant. The first part is fairly easy to identify, but the second is considerably difficult since we do not have information on the varieties that the farmers could have planted but declined to. We consider that if a variety is available to some minimum percentage of farmers, market forces will naturally increase its availability if it is desirable. In order to establish a level at which we would consider varieties available in the community, the data were examined for a natural break that would differentiate between varieties that would be available to any farmer who was interested in planting them and those that may be 'heirloom' varieties that single farmers or families keep for themselves. This led to the elimination from the study of any variety that was planted by less than ten percent of the farmers in each community. There was another observed natural break that would have only kept the one to three most popular varieties in each community (one in Toralapa, one in Morochata, three in Colomi). This would have eliminated most of the information in the sample and was not considered to be an accurate picture of the data. It would have resulted in estimation of most household's preferences from only variety, when very few households only plant one variety. The major caveat to this is that we would be underestimating the importance of new varieties that have not yet been widely disseminated and achieved equilibrium supply. High levels of familiarity with the varieties in the study were exhibited both by farmers and by technicians, so it seems logical to assume that this is not an issue.

We are left with eleven varieties which we will use to estimate the model. All eleven are present in Colomi. In Morochata three are widely observed, with limited observations of two more. The limited observations consist of a small number of households (one or two) that planted a variety that was part of the choice set in another region. Since data were collected on the attributes of these varieties, the positive results are included in the estimation. Missing results, or households that did not plant these varieties are not included. Toralapa also had three of the varieties present.

We construct a binary choice model where each household has an opportunity to plant each variety in their local choice set. Edmeades and Smale, whose general framework is similar, use a zero-inflated poisson (ZIP) model using observations on the number of banana trees planted for each variety of banana. The data from Bolivia occur in counts (bags of seed) but these counts measure different units (different sizes of seed in the bag). When they are made equivalent, they do not resemble a segmented count distribution. Instead, we chose a tobit model, where each household first decides whether or not to plant the variety and then decides how much to plant. This represents a form of Amemiya's type 2 tobit model (Amemiya, 1985, Cameron and Trivedi). Both the tobit and the ZIP model assume distributions with some concentration of zeros. The tobit uses a normal distribution for the non-zero observations, whereas the ZIP, as its name implies, uses a poisson.

We observe how much a household plants of each variety in its choice set, as either zero or a positive number. We do not observe the selection process that households undertake by evaluating the expected utility from each variety. Each household has a minimum expected utility that must be met or exceeded by a variety in order for the household to plant that variety. This process is modeled by the first stage of the econometric model. A second stage then determines the levels of each chosen variety (which we observe), while accounting for the selection process that has occurred. Formally:

1. $Y_{in} = Z_{ik}^{1} B_{k}^{1} + X_{ijn}^{1} T_{ij}^{1} + U_{in}^{1}$

(this is the unobserved evaluation of the variety that equates to the expected utility provided by growing the variety)

2. $V_{in} = Z_{ik}^2 B_k^2 + X_{ijn}^2 T_{ij}^2 + U_{in}^2$

(this is observation of planting amounts for varieties where Y>0, which matches eq. 10 in the analytical model)

3. $E\left(V_{in} \vdots Z_{ik}^2, X_{ijn}^2, Y_{in} \geq 0\right) = Z_{ik}^2 B_k^2 + X_{ijn}^2 T_{ij}^2 + E\left(U_{in}^2 \vdots U_{in}^1 > -\left(Z_{ik}^1 B_k^1 + X_{ijn}^1 T_{ij}^1\right)\right)$

where i indexes varieties, k indexes variety characteristics, j indexes household characteristics and n indexes the households. The parameters superscripted with 1 correspond to variables present in the first stage (variety selection) estimation, those with 2 to variables in the second stage (levels of selected varieties). The B parameters correspond to variety characteristics in both stages. Note that Betas do not vary by variety. This means that variety characteristics have the same impact regardless of variety. The household parameters are indexed by variety, to allow them to impact adoption of varieties differently.

The system was estimated in Stata, using the maximum likelihood version of the Heckman command (models with sample selection). This uses the Heckman log likelihood function:

$$\ln(l) = \sum_{y=0} \ln(1 - \Phi(z_1 b_1 + x_1 t_1)) + \sum_{y=1} \ln(\frac{1}{\sqrt{2\pi\sigma^2 u_2}}) + \sum_{y=1} \ln(v - (z_2 b_2 + x_2 t_2)^2$$

$$+ \sum_{y=1} \ln \Phi((z_1 b_1 + x_1 t_1) + \rho((v - x_2 b_2 + x_2 t_2) / \sigma_{u2}) / (\sqrt{(1-\rho)^2})$$

Because this involves multiple observations from each household, standard errors were corrected for clustering on the household (indexed in the data by a household ID number or hhid) to avoid overstating the efficiency due to an artificially high number of observations.

This model is identified without exclusion restrictions between the selection and levels variables, in theory due to differences in the functional form of the first and second stages of the problem. However, it is “close to unidentified” (Cameron and Trivedi). In practice this leads to identification by distributional assumptions. It may be advantageous to use exclusion restrictions to obtain identification. This means we assume that the set of covariates in the first stage is not identical to that in the second stage, that at least one covariate is different. Using any of the household/farm/regional characteristics did not seem desirable, as there are no clear hypotheses about how these will impact every situation. Instead, non-identical measures of yield were used in the different stages. Lowest yield was used in the first or selection stage, and expected yield was used in the second stage. In the penultimate version, however, the lowest yield variable was not statistically significant. Expected yield was substituted, but this was not statistically significant either. Likelihood ratio tests could not reject the hypothesis that coefficients on the selection stage yield variables were zero. Other literature (for example, Dalton) suggests that farmers in LFAs do not place a high weight on yield during variety selection. So the yield variable was excluded from the selection portion of the model to aid in identification.

3.6 Summary

Data collection and empirical model design were both required tradeoffs and assumptions. While this does imply some limitations, because the survey and estimation process were designed together, these limitations are well known and understood and can be taken into account when interpreting model results. Additionally, these limitations do not keep us from achieving the goal of the project, which is to understand how production characteristics of potato varieties impact farmers planting decisions.

4. Data Summary and Description of study area

This chapter presents a description of the study area, and comparisons between the three communities in the sample. Demographic and household statistics are presented for the whole study area and for each community. Subjective descriptions of the community are included to contrast conditions in each. This is followed by information about potato varieties currently being planted, their characteristics and those chosen for further analysis.

4.1 Description and Statistics- Pooled

Table 4.1 shows demographic and household asset characteristics of the study area as a whole. A few points should be made in addition to presentation of the statistics. Farmers were asked about the source of the seed they planted and what type of seed it was (see survey in appendix, Modulo 6). Sources of seed include owned or kept from previous harvest, purchased in market, purchased from an institution, and acquired from family members. Types of seed included local, selected and certified. Certified and Selected seed was reported in conjunction with 'owned' as the source in some cases. This may imply that improved seed was acquired some time ago from commercial or institutional sources and the current 'owned' seed is descendant from that stock. If not all households responded in this way, there may be more widespread use of improved seed, but it may not be an annual purchase. Households may purchase seed material from commercial or institutional sources every few years, and use seed kept from year to year in the intervening years.

All variables describing area planted in potatoes are a calculation. PROINPA felt that the areas reported in their recent household survey of Tiraque were inaccurate, and suggested that it would be more accurate if farmers stated the amount (measured in 'cargas', about 109kg) and size (first, second, third, fourth with first being the largest) of the potato seed they planted. This was then translated into an area measurement in order to have an equivalent measure for all sizes. This translation was accomplished using figures provided by PROINPA on typical planting densities (Unidades y Equivalencias, appendix).

Most of the households in the sample (and all of those outside Colomi) list potato as their primary crop. Papalisa, another Andean root crop, and haba, or fava beans, are the other crops that a handful of households state are their primary crop. Many also buy potatoes in market for consumption, possibly due to their temporal cash management strategy, price differentials which may allow them to generate greater income at certain times of the year as well as a desire to consume varieties that are not grown or are not grown in sufficient quantities by the household. About 40% of the households that report purchases have more than the mean area planted to potatoes. It seems likely that many of the purchasers encounter shortages at some point in the year, but not all. Of the 22 (15%) households that report purchasing potatoes, only 1 does not list potato as its most important crop.

Table 4.1: Summary Household Statistics (Pooled across all communities)

variable	mean	sd	description
size	5.6	2.4	number of household members
sowers	3.1	1.7	household members participating in sowing crop
harvesters	3.33	1.74	household members harvesting
age	42.66	13.59	age of HH head
basiced	0.79	0.41	d=1 if HH head has a basic education
seconded	0.06	0.23	d=1 if HH head has a secondary education (base group is no educ)
member	0.76	0.43	d=1 if HH is member of farmer org
farmerorg	0.84	0.37	d=1 If HH reports existence of farmer org in area
contact	0.72	0.45	d=1 if HH has regular contact with extension
weekly	0.58	0.5	d=1 if HH visits market weekly (other options are less often)
nflm	0.31	0.85	number of persons participating in non-ag income activities
hired	0.47	0.5	d=1 if HH hired labor for farm last year
credit	0.15	0.36	d=1 if HH received a loan
primary	0.95	0.22	d=1 if HH states that potato is most important crop
purchase	0.19	0.4	d=1 if HH purchases potatoes
impuse	0.31	0.46	dummy=1 if HH reports using selected or certified seed
count	3.5	2.38	number of varieties planted by HH
area	0.67	0.68	total area planted to potatoes (calculation)
insample	0.6	0.62	area planted to 11 project varieties
percin	0.9	0.15	insample/area
irrigation	0.54	0.5	d=1 if HH assigns labor to irrigation
plows	1.19	0.87	no. of plows owned
toros	0.54	0.5	d=1 if HH has at least 2 bulls
livestock	9.45	8.22	approx. value of livestock in 1000s Bs.
cocina	0.64	0.5	d=1 if HH owns a mfd. stove
tv	0.32	0.47	d=1 if HH owns a television

Source: Encuesta de Variedades de Papa; Field survey of 145 Cochabamban farm households, implemented Nov. 2007 by SANREM CRSP.

4.2 Description and Statistics-Communities

All three communities surveyed are remote rural communities in the central Bolivian highlands. Rainfall, temperature and other climatic conditions vary between the villages, although it is probably true that the variation over time in each place is greater than the variation across the regions. For example, average rainfall in January (the height of the rainy season) from 1996-2007 in Colomi and Tiraque was 143.5mm and 124.7 mm respectively (data from SENAMHI, see appendix). Within that time, measurements for Colomi in January range from 48.3 to 219.9, and in Tiraque from 25.2 to 230.5 in the same month (all in mm). There is no weather station in Morochata, so climatic data are not available for that region. Comprehensive climatic data are available for Tiraque, but conditions at the station may not reflect conditions in individual farmer fields. Differences in altitude, which can be related to temperature and rainfall, are the primary reason for this. We can compare rainfall amounts from Tiraque and Colomi; averages for Colomi are higher than for Tiraque, although Tiraque records higher highs, and lower lows, than Colomi. This suggests that Tiraque may face higher drought and flood risks.

The locations of the three communities contribute to differences in market access and remoteness. Tiraque/Toralapa and Colomi have easy access to Cochabamba via public taxis on paved roads. From either location, the journey takes approximately 90 minutes, if weather and traffic are not a problem and there are no government road blocks (the roads that pass these areas go east, towards coca growing regions). Anecdotal evidence suggests that residents of Colomi also have access to market opportunities in Chapare (another metropolitan area to the east of Cochabamba), particularly for work. Morochata is the most remote of the areas surveyed. Between Morochata and Cochabamba there is a high mountain pass, with cobblestone paving in some areas, that appears to suffer from ‘washing out’ on a regular basis. When the research team traveled to Morochata from Cochabamba it was a three hour journey. Public transportation does not traverse this route; the main civilian method to travel between Morochata and Cochabamba is by hitching a ride on commercial cargo haulers (potato trucks were observed with up to a dozen passengers riding on the cargo).

Table 4.2: Summary Household Statistics- Individual Communities

	Colomi		Morochata		Toralapa	
variable	mean	sd	mean	sd	mean	sd
size	5.8	2.4	5.4	2.5	5.35	2.23
sowers	3.15	1.71	3.09	1.77	3.00	1.52
harvesters	3.51	1.78	3.18	1.79	3.15	1.39
age	42.88	14.7	43.54	12.88	39.45	11.6
basiced	0.76	0.43	0.86	0.35	0.7	0.47
seconded	0.06	0.24	0.05	0.23	0.05	0.22
member	0.56	0.5	0.95	0.23	0.9	0.3
farmerorg	0.68	0.47	1	0	0.95	0.22
contact	0.69	0.47	0.7	0.46	0.9	0.3
weekly	0.79	0.4	0.23	0.42	0.85	0.37
nflm	0.46	1.06	0.21	0.67	0.1	0.3
hired	0.54	0.5	0.32	0.47	0.65	0.49
credit	0.22	0.42	0.05	0.23	0.2	0.41
primary	0.9	0.3	1	0	1	0
purchase	0.24	0.43	0.07	0.26	0.4	0.5
impuse	0.31	0.47	0.32	0.47	0.3	0.47
count	5.22	2.27	2.07	1.15	1.75	1.02
area	0.65	0.4	0.52	0.64	1.17	1.18
insample	0.57	0.38	0.46	0.49	1.13	1.14
percin	0.86	0.16	0.93	0.16	0.98	0.05
irrig	0.13	0.34	0.93	0.25	0.85	0.37
plows	0.93	0.83	1.4	0.8	1.45	0.99
toros	0.47	0.5	0.52	0.5	0.8	0.41
livestock	8.15	7.05	9.55	8.84	13.62	9.10
cocina	0.69	0.47	0.54	0.5	0.7	0.47
tv	0.44	0.5	0.16	0.37	0.4	0.5

Source: Encuesta de Variedades de Papa, SANREM CRSP; Colomi, N=68; Morochata, N=57; Tiraque, N=20

Looking at tables 4.2 and 4.2a, we can see how the frequency of market visits (weekly), hiring of labor (hired), ownership of tvs and access to credit are all lower in Morochata. This relates to the remoteness discussed above. All of these variables measure market access of some kind. Colomi’s increased access to the non farm labor market is represented in the highest mean of household members participating in that market. The level of irrigation use in Morochata is very high, and may point to a problem in the variable. The variable is drawn from a question about labor allocation (Modulo 10), and represents the proportion of households that assign labor to irrigation. The high number may be due to a misunderstanding of the question. It may also represent a sampling problem. One of the survey villages in Morochata was beside a river. Table

4.2a presents the results of ANOVA and t-tests to examine differences between the three communities.

Table 4.2a Differences Between the Communities According to Household Statistics

	Anova		T-test			
Variable	F	p	t(2,3)	t(1,3)	t(1,2)	
size	0.58	0.56				
sowers	0.06	0.94				
harvesters	0.72	0.49				
age	0.68	0.5				
basiced			1.6	0.58	-1.3	all
seconded			0.04	0.15	0.15	all
member			0.71	-2.88	-5.36	2,3
farmerorg			1.71	-2.5	-5.18	2,3
contact			-1.78	-1.88	-0.13	all
weekly			-5.84	-0.55	7.6	1,3
nflm	2.01	0.14				
hired			-2.7	-0.83	2.61	1,3
credit			-1.99	0.19	2.72	1,3
primary			!	-1.5	-2.5	2,3
purchase			-3.87	-0.92	2.77	1,3
impuse			0.13	0.07	-0.08	all
count	61.29	0				
area	7.67	0.0007				
insample						
percin						
irrig			1.06	-8.13	-14.5	2,3
plows			-0.21	-2.35	-3.24	2,3
toros			-2.16	-2.67	-0.61	1,2
livestock	3.55	0.03				
cocina			-1.03	-0.07	1.45	all
tv			-2.29	0.32	3.54	1,3

Source: Encuesta de Variedades de Papa, SANREM, Nov. 2007. t(i,j) is a t-test for differences between groups i and j. Colomi=1, Morochata=2, Tiraque=3

4.3 Variety Incidence

Table 4.3 shows us the mean area planted to each variety in each community, and in the entire survey, for the households that report planting the variety. Farmers in Tiraque generally specialize in Waych'a, and in Morochata Waych'a and HH occupy the most area. Colomi shows less tendency to specialize, with a more uniform distribution of means across varieties. Cross referencing with table 4.6 shows that the varieties with smaller mean areas are lower yielding varieties. Table 4.4 reports the number and percentage of households that grow each variety.

Table 4.3: Average Calculated Area Planted to Varieties, in the Pooled Sample and in Each Community (conditional on selection of the variety)

Variety	Pooled mean	sd	Colomi mean	sd	Morochata mean	sd	Tiraque mean	sd	obs
Waych'a	0.4	0.58	0.16	0.18	0.363	0.218	1.08	1.16	124
HH	0.24	0.46	0.19	0.16	0.49	1.07	0.067	0	52
Pinta Boca	0.086	0.076	0.1	0.08	0.035	0.035	0		50
Candelero	0.072	0.049	0.07	0.04	0.08	0	0.2	0	29
Puca Niawi	0.14	0.096	0.13	0.07	0		0.263	0.181	31
Rosita	0.217	0.27	0.22	0.27	0.08	0	0		29
Qorisongo	0.12	0.075	0.11	0.07	0.15	0.09	0		30
Yana Qollyu	0.08	0.06	0.11	0.05	0.005	0.003	0.014	0.012	16
Wawilo	0.06	0.04	0.07	0.04	0.005	0	0		18
Imilla Blanca	0.14	0.16	0.14	0.16	0		0		11
Bola Qollyu	0.05	0.024	0.05	0.02	0		0		8

Source: Modulo 6, Encuesta de variedades de papa, SANREM CRSP, Nov 2007

Table 4.4: Number and Percentage of Households Planting Each Variety

variety	All obs	% hh's	Colomi obs	% hh's	Morochata obs	% hh's	Tiraque obs	% hh's
Waych'a	124	85	48	70	56	98	20	1
HH	52	35	42	61	9	16	1	05
Pinta Boca	50	34	37	54	13	24	0	0
Candelero	29	20	27	39	1	02	1	05
Puca Niawi	31	21	28	41	0	0	3	15
Rosita	29	20	28	41	0	0	0	0
Qorisongo	30	21	26	38	4	07	0	0
Yana Qollyu	16	11	11	16	2	04	3	15
Wawilo	18	12	17	25	0	0	0	0
Imilla Blanca	11	08	11	16	0	0	0	0
Bola Qollyu	8	06	8	12	0	0	0	0

Source: Encuesta de Variedades de Papa, SANREM CRSP, Nov 2007. All: N=145; Colomi: N=68; Morochata: N=57; Tiraque: N=20

In total, 145 household surveys returned 55 different potato variety names. At least two were not specific varieties, but groups of related varieties (Qollyu and Toralapa), and two others (at least) were alternate names of the same variety (Yunguy/Puca Niawi and Runa Toralapa/HH). Waych'a was the most common variety of potato in all three communities, and is generally considered to be the most important variety in Bolivia (Thiele et al).

4.4. Variety Characteristics

Two types of data were collected in the evaluation of variety characteristics. Farmer impressions/perceptions were evaluated using data from the household surveys. Farmers were asked how they perceived individual variety performance under different risk characteristics. Each farmer was asked whether they believe a particular variety is highly affected, weakly affected or not affected by frost, drought, hail, pests and disease. Technician opinions were also collected. Each variety was classified as either highly susceptible, moderately susceptible, moderately tolerant/resistant or highly tolerant/resistant to frost, drought, hail, pests and blight according to experience and beliefs solicited during an interview with a potato breeding specialist (Table 4.5). Both farmers and extension workers gave expectations of yield. Farmers stated an expected multiplication rate (cargas of seed to cargas of harvested potatoes) during the survey process, and extension workers gave high, normal and low yields for each variety in their relevant districts on a survey form completed in early 2008. These were used to calculate expected value and variance from a triangular distribution. PROINPA publications also provided some information and confirmation.

Table 4.5: Potato Breeder's Statements of Variety Characteristics

variety	index #	Frost	Drought	Hail	Blight	Pests
Waych'a	1	R	R	R	R-b	S-a
HH	2	S-a	S-a	S-a	R-a	S-a
Pinta Boca	3	S	S	S	S	S
Candelero	4	S	S	S	S	S
Puca Niawi	5	S	S	S	R	S
Rosita	6	S-a	S-a	S-a	R	S-a
Qorisongo	7	S-a	S-a	S-a	R-a	S-a
Yana Qollyu	8	R	R	R	R	R
Wawilo	9	R	R	R	R	R
Imilla Blanca	10	S	S	S	S	S
Bola Qollyu	11	R	R	R	R	R

Source: Julio Gabriel, Fundacion PROINPA Potato Breeding Program; R indicates that a variety is resistant or tolerant to the factor; S indicates that it is susceptible. An a afterwards indicates further that the variety is considered highly resistant/susceptible; b indicates low levels of the characteristic.

Difficulties were encountered when surveyors attempted to gather data on variety performance under adverse conditions from farmers. Data from farmer perceptions suggest that farmers do not differentiate between varieties in terms of reaction to pests or climatic conditions. Differences in perception of disease reaction was, however, common. Of the 145 households surveyed, about twenty reported knowledge of only one variety. Of the remainder, more than half differentiated among the varieties they were familiar with for performance under blight conditions. Less than one fifth differentiated among the varieties they were familiar with for performance under adverse conditions related to pests, frost or drought. Average values for each variety are presented in table 4.6. Most of this fits with the potato breeder statements. The blight resistance of Waych'a comes under question when examining farmer data. Because of this conflict, other information was sought out. Earlier publications by PROINPA were used to provide more information about variety characteristics, particularly one titled "Variedades de Papa y Oca de la Zona Candelaria." When available, information on varieties was taken from or confirmed by this text. The two changes resulting from this were the characterization of Waych'a as susceptible to blight, and of Qorisongo as resistant to frost. Other variety characteristics were modeled according to potato breeder statements. The primary reason for favoring potato breeder statements was that it would avoid the problem of farmers needing to separate their risk exposure levels from the performance of varieties relative to each other.

Table 4.6: Farmer Statements of the Impact of Late Blight on Potato Varieties

variety	average score	sd
Waych'a	1.31	0.48
HH	2.03	0.83
Pinta Boca	1.36	0.52
Candelero	1.27	0.45
Puca Niawi	1.88	0.8
Rosita	1.97	0.87
Qorisongo	2.06	0.88
Yana Qollyu	1.24	0.44
Wawilo	1.31	0.58
Imilla Blanca	1.24	0.44
bola Qollyu	1.4	0.89

Source: Modulo 9, Encuesta de Variedades de Papa, SANREM CRSP, Nov. 2007. Each farmer scored varieties according to the following scale: 1. greatly affected; 2. moderately affected; 3. not affected; 4. favored

Since most farmers (about 80%) believed that all the varieties that they planted had the same reaction to pests, disease, frost and drought, these numbers are not considered in the study. They would be more closely related to individual farmers relative levels of optimism and pessimism regarding these factors, but not of the relative performance of different potato varieties under these conditions.

Table 4.7: Mean and Variance Drawn From Technician Statements of Yield

	Colomi		Morochata		Tiraque	
Variety	Expected	Variance	Expected	Variance	Expected	Variance
Waych'a	8	2.17	15	16.67	18.33	43
HH	15.67	5.05	16	26	22.67	54
Pinta Boca	7.83	1.56	6	2.67	14.67	
Candelero	6.67	2.06	5.33	1.56	12.67	20.2
Puca Niawi	11.17	4.18	no obs		23.3	43.05
Rosita	15.67	5.05	20.33	31.06	no obs	
Qorisongo	11.5	3.04	9.67	5.06	no obs	
Yana Qollyu	7.17	1.76	6	5.17	13.67	13.72
Wawilo	8.67	3.13	6	2.67	no obs	
Imilla Blanca	7.83	1.56	no obs		18.67	37.38
Bola Qollyu	7.17	1.76	no obs		no obs	

Except where it was used to confirm or deny technician beliefs (Waych'a and blight, above) the data from farmers was not considered usable in the final model. Since so few farmers expressed knowledge of varieties that they were not currently growing, it would be difficult to use this data in a model that accounts for the choice to not grow varieties that are available in the surrounding area. The opinions of PROINPA technicians regarding variety performance and yield are considered applicable to all the farm-households in the survey.

Table 4.8 Households taking action against risk factors

Factor	% of hh's take action
drought	19
hail	20
frost	40
pests	97
blight	92
poor soils	72

One other type of information that was collected during the field surveys may shed light on levels of risk exposure. Farmers were asked whether or not they performed any action to specifically combat any of the following risks: drought, hail, frost, pets, blight and poor soils. The percentage of households that responded positively, that reported having taken some action to avert these risks is reported in table 4.8.

4.5 Farmer and Technician Beliefs Compared

Table 4.9: Summary of farmer and technician statements of variety characteristics

Characteristic		Variety	mean	sd	1	2	3	obs	Potato Breeder
Frost		all	1.75	0.7	242	280	91	613	
	1	Waych'a	1.73	0.64	47	67	13	127	R
	2	HH	1.96	0.77	16	22	14	52	S-a
	3	Pinta Boca	1.71	0.78	25	17	10	52	S
	4	Candelero	1.75	0.75	12	11	5	28	S
	5	Puca Niawi	1.75	0.72	13	14	5	32	S
	8	Rosita	1.69	0.76	14	10	5	29	S-a
	11	Qorisongo	1.63	0.61	13	15	2	30	S-a
	14	Yana Qollyu	1.69	0.7	7	7	2	16	R
	15	Wawilo	1.67	0.77	9	6	3	18	R
	17	Imilla Blanca	1.73	0.79	5	4	2	11	S
	18	Bola Qollyu	1.63	0.74	4	3	1	8	R
Pests		all	1.51	0.56	318	273	19	610	
		Waych'a	1.4	0.52	77	47	2	126	S-a
		HH	1.77	0.67	19	26	7	52	S-a
		Pinta Boca	1.52	0.54	26	25	1	52	S
		Candelero	1.57	0.5	12	16	0	28	S
		Puca Niawi	1.63	0.55	13	18	1	32	S
		Rosita	1.48	0.57	16	12	1	29	S-a
		Qorisongo	1.5	0.51	15	15	0	30	S-a
		Yana Qollyu	1.69	0.8	8	5	3	16	R
		Wawilo	1.67	0.49	6	12	0	18	R
		Imilla Blanca	1.63	0.5	4	7	0	11	S
		Bola Qollyu	1.25	0.46	6	2	0	8	R
Drought		all	1.85	0.68	188	297	99	584	
	1	Waych'a	1.79	0.69	41	55	17	113	R
	2	HH	2.14	0.72	10	24	17	51	S-a
	3	Pinta Boca	1.94	0.67	12	27	9	48	S
	4	Candelero	1.68	0.72	13	11	4	28	S
	5	Puca Niawi	1.94	0.72	9	16	7	32	S
	8	Rosita	1.79	0.73	11	13	5	29	S-a
	11	Qorisongo	1.7	0.75	14	11	5	30	S-a
	14	Yana Qollyu	1.94	0.85	6	5	5	16	R
	15	Wawilo	1.67	0.69	8	8	2	18	R
	17	Imilla Blanca	1.73	0.65	4	6	1	11	S
	18	Bola Qollyu	1.75	0.7	3	4	1	8	R

Blight	all	1.53	0.7	360	177	73	610	
1	Waych'a	1.32	0.49	87	39	1	127	R-b
2	HH	2.13	0.82	14	17	21	52	R-a
3	Pinta Boca	1.4	0.53	32	18	1	51	S
4	Candelero	1.29	0.46	20	8	0	28	S
5	Puca Niawi	1.78	0.75	13	13	6	32	R
8	Rosita	1.86	0.83	12	9	8	29	R
11	Qorisongo	2.03	0.87	10	8	11	29	R-a
14	Yana Qollyu	1.25	0.44	12	4	0	16	R
15	Wawilo	1.33	0.59	13	4	1	18	R
17	Imilla Blanca	1.36	0.5	7	4	0	11	S
18	Bola Qollyu	1.25	0.46	6	2	0	8	R
Yield Multiplier (potatoes/seed)				Technician-Colomi (t/Ha)			obs	
1	Waych'a	9.5	3.7	8			126	
2	HH	14.9	6.6	15.7			51	
3	Pinta Boca	8.9	3.2	7.83			51	
4	Candelero	8.3	3.1	6.67			27	
5	Puca Niawi	14.9	6.3	11.2			31	
8	Rosita	14.8	8.1	15.7			27	
11	Qorisongo	12.1	6.8	11.5			30	
14	Yana Qollyu	9.9	5.6	7.17			16	
15	Wawilo	11.3	5.1	8.67			16	
17	Imilla Blanca	8.6	6.1	7.83			11	
18	Bola Qollyu	9.9	3.1	7.17			8	

Source: Encuestas de Variedades de Papas, SANREM, Nov. 2007; Interview with Julio Gabriel, Nov. 2007; Encuesta Sobre Variedades de Papa- Caracteristicas de Variedades, SANREM, Mar 2008 Farmer statements key: 1-variety is greatly affected; 2- variety is moderately affected; 3- variety is not affected; 4-variety is favored by this condition.

Looking at the first part of table 4.9, we see that the mean of farmer statements of variety reaction to frost is 1.75 on a 1, 2, 3 Liekert scale. Only HH has a higher averaged score than the mean, with most varieties at or slightly below the mean. In general, farmers don’t seem to differentiate between different varieties in terms of reaction to frost. Leaving out the highest and the lowest, the other varieties average between 1.67 and 1.75. Given the possible inputs that generate this average (farmers answered with a 1, 2 or 3), this is very little variation. Within this group, we have varieties that the potato breeder considered to be highly susceptible, susceptible and resistant to frost. Farmer impressions of HH seem to be different than that of the technician; farmers see it as one of the better varieties in frost conditions, whereas the potato breeder stated that it was highly susceptible.

The impressions of tolerance of pests are also not very congruent. Many farmers seemed to believe that HH is resilient, though the breeder stated that it was highly susceptible. This also applies to impressions of drought, though with drought impressions it applies to Pinta Boca and Puca Niawi as well as HH; farmers often state that these varieties are less affected by drought, though the potato breeder believed them to be susceptible.

When we get to blight, we see more agreement from the two sides. HH, Puca Niawi, Rosita and Qorisongo are viewed by both sides as being less affected by blight. Breeder statements suggest that several other varieties (Yana Qollyu, Wawilo and Bola Qollyu) are resistant, though the farmers did not agree. It should be noted that the averages of farmer statements for these varieties come from very small samples, and that there is a lot of room for error there.

Looking at the overall picture, HH and Puca Niawi are more often viewed by farmers as hearty/resistant than other varieties. Each of these score at or above the average for all the observations. They also have the highest averages for the yield multiplier. HH has an average score equal to or better than any other variety for all areas of evaluation by farmers. It is the second most common variety to Waych'a, which comes in the middle or lower tiers according to all farmer evaluated characteristics. HH occurs in 52 observations, accounting for about 14% of the calculated area planted in the entire sample. Waych'a occurs 124 times, accounting for about 57% of the calculated area planted. This disparity suggests that the characteristics that are not being measured in this survey are very important to determining variety choice and planting amounts by farmers. The predominance of Waych'a in the field cannot be explained by farmer perceptions recorded here. Therefore, we must conclude that consumption and marketing characteristics of Waych'a are the driving force behind its place as the most popular variety to plant.

Table 4.9 allows us to compare technician and farmer evaluations of the varieties side by side. Some things we should note: these three digit averages (for the farmers beliefs) are drawn from statements made using a Liekert scale. Farmers answered with a 1, 2, or 3, corresponding to whether they felt that the variety in question was greatly affected, moderately affected or not affected. They also had the option to answer 4 : that the variety is favored by the factor in question, though no 4s were recorded. Each farmer answered about each variety that he or she was familiar with. This was mostly the varieties that the farmer plants, but in some cases included varieties planted in the past and since discontinued. The means presented are averages of the farmers statements. Since the farmers answered with one digit, it may not be accurate to examine averages that are drawn out more than one digit. If we take the above averages to only one digit, we see that all values for frost and drought would be 2, and Waych'a and Bola Qollyu would be the only non-2 values for pests (they would both be 1, though not with great statistical confidence). Only in the beliefs about reaction to blight do we see any stratification between varieties, with HH, Puca Niawi, Rosita and Qorisongo all averaging near two, while all others average near one.

Farmer statements about yield are not generally stated in the same way that technicians state their beliefs about yield. Farmers regularly view yield from a multiplication basis, evaluating how many cargas of harvested potatoes they will retrieve from each carga of seed that they plant. Technicians evaluated yields in terms of tons/Hectare. The fact that these two scales result in scores of a similar magnitude does not mean that they can be directly cross compared. For example, a technician statement of 15 t/Ha is NOT 50% more than a farmer statement of a multiplier of 10 cargas harvested per carga of seed. What we do see is that the farmer averages correspond fairly well with the technician statements. Farmers have more faith in the productivity of Puca Niawi than do technicians, ranking it among the most productive, whereas technicians seem to put it in the second tier.

4.6 Summary

Descriptive statistics give us a general picture of the study area. Since there were few preconceptions of the study area its hard to comment much on the statistics. Household head age and education, and household size are almost identical for the three communities. Colomi has the most potato diversity, Tiraque the least. Geography is the major factor in differentiating the three communities, and most other factors that are different can be traced to geographic origins.

5. Results

This chapter presents the numerical results of the empirical estimation. These results will be interpreted from an economic perspective and their practical importance for Bolivian agricultural development will be discussed. Shortcomings of the model and possible impacts on the results will be discussed.

We use the survey data to estimate a type 2 tobit model that evaluates variety and household characteristics as factors in the household variety choice decision. We estimate a quantity planted dependent variable model for each variety. The quantity planted is expressed as a function of household and potato variety characteristics. It is important to remember that we are not claiming to have completely modeled the decision process, but that we have attempted to account for all the aspects that we can given the conditions in the field and our capacity for data collection. This model is sufficient to realize our main goal, that of understanding of how variety characteristics relating to productivity under adverse conditions impact variety choice. There are some ways in which additional data could have improved the model, but as it stands we can say with confidence where there is a relationship, and with some certainty which relationships are stronger than others.

Logarithms of continuous variables were used. The dependent variable, which is a proxy for surface area in hectares dedicated to a single variety, was used in log form, as was expected yield for each variety, a right hand side variable. The log of livestock value was tested, but made the log-likelihood function intractable (Stata could not find a solution on a convex area) so the untransformed approximate values were used instead. Several variables not included in the final model were tested and rejected by likelihood ratio tests. These include the variables detailing the age and education of the household head, which were left out of the final version of the model. Variance of the triangular distributions of expected variety yield was also excluded, due to high levels of correlation (over 50%) with the yield variable, and a high probability that it is measured with error (because yield may not be distributed triangularly). Variance was included in early versions of the model that returned unusual/unexpected results. Blight resistance, moderate and high, which both farmers and technicians had distinct opinions on was included in the model, as was frost tolerance/susceptibility. Farmer opinions on frost tolerance were less definite (see section 4.4) but it was included in the model according to technician beliefs out of interest in the impact of frost and as a check to ensure that farmer's stated preferences for potato variety characteristics are congruent with their revealed preferences.

The overall picture that we get from the model fits with prior expectations. Not all coefficients on the variables of interest are what were expected, but economic theory and examination of the assumptions made is helpful in finding likely reasons for the deviations from prior expectations. These explanations of the deviations from theory can be used to draw conclusions about our goals and about the state of potato variety selection in central Bolivia.

Table 5.0: Variables Used in Estimation

variable	stages	description
size#	1,2	number of household members
member#	1,2	d=1 if HH is member of farmer org
wkly#	1,2	d=1 if HH visits market weekly (other options are less often)
nflm#	1,2	number of persons participating in non-ag income activities
hired#	1,2	d=1 if HH hired labor for farm last year
credit#	1,2	d=1 if HH received a loan
prim#	1,2	d=1 if HH states that potato is most important crop
lstock#	1,2	approx. value of livestock in 1000s Bs.
cocina#	1,2	d=1 if HH owns a mfd. stove
area#	1	calculated area planted in potatoes (Ha.)
frost tolerance	1,2	d=1 if variety is frost tolerant
frost suscept.	1,2	d=1 if variety is susceptible to frost
Blight res. high	1,2	d=1 if variety ahs high level of blight resistance
Blight res.	1,2	d=1 if variety has moderate level of blight resistance
ly	2	log of expected yield
lv	2	log of calculated area planted to variety

Note: variables followed by # are indexed in the estimation and results by the variety index numbers provided in table 4.5

We estimate the quantity planted of each variety as a function of household and variety characteristics. This means that each household characteristic occurs eleven times in the dataset. Each occurrence corresponds to the relationship between the household characteristic and the quantity planted of a specific variety. The results that follow were obtained using the maximum likelihood version of the Heckman command in Stata, which is a two stage model that accounts for the unobserved selection process. The first stage models the relationships that correspond to variety selection, and the second stage models the impact of RHS variables on the amount that is planted of each variety that a household selects. Selection of varieties (the first stage) was modeled as a function of frost susceptibility, frost tolerance, average resistance to late blight, and high resistance to late blight. All of these are dummy variables that are equal to 1 if the variety falls into the category, and equal to zero otherwise. This was conditioned on nine household characteristics for most varieties. Use of credit and non-farm labor market participation were not modeled as impacting selection of Imilla Blanca, because no households that planted this variety accessed these markets. Weekly market visits were left out of the conditions for selection of Bola Qollyu for reasons of collinearity as well.

The second stage of the model characterizes the amount of each selected variety that a household plants as a function of the same household characteristics, frost and blight variables and adds expected yield. The collinearities that require variables to be removed in the first stage are present in the second stage as well, so those variables are removed in both stages. A summary of which variables are in each stage of the model is presented in table 5.0.

Impacts of individual household characteristics on variety selection and amount planted of selected varieties are examined in the following section. Coefficients that are statistically significant at the 10% level are discussed. Impacts on both stages of the model are brought up and interpreted. Signs of the non-significant coefficients are discussed where appropriate. Tables containing the significant coefficients in both stages as well as one summarizing the signs and significance levels of all coefficients are presented after the verbal analysis.

5.1 Results and description- Household characteristics

Household Size (size#)

This variable is a count of the number of members of the household. The negative coefficients on size in table 5.1 (size4, size8, size10, size11, in table 5.1) tell us that, all else equal, larger households are less likely to select the lower yielding native varieties. In addition to those coefficients, the estimated effect on varieties 3 and 9 was negative, though not significant at the ten percent level (table 5.3). All six of these varieties are lower yielding. The impacts of household size seen in the model are congruent with the prior hypothesis that larger households will avoid low-yield varieties. The corollary to this, that larger households would be more likely to select high yielding varieties is implied by the signs presented in table 5.3, though these results are not significant at the ten percent level.

Turning to the second stage of the model, the prior hypothesis is that larger households, with more dependents, will be more concerned with consumption shortfall. This should lead to larger plantings of high yielding and hearty varieties. According to the results in table 5.2, larger households will tend to exhibit less extensive plantings of several blight tolerant varieties (Puca Niawi-size5, HH-size2, Qorisongo-size7, Yana Qollyu-size8), when they are selected, than otherwise similar small households. This is contrary to our expectations, but may suggest that larger households tend to have different risk preferences than smaller households. They may have an increased concern about risks other than blight, and plant varieties that will help to offset those other risks, instead of concentrating on larger plantings of blight resistant varieties. Larger households also exhibited a tendency to plant less area to Imilla Blanca (size10, table 5.2), conditional on that variety being selected, than small households. This is a low yielding variety, as are several of the blight resistant varieties mentioned above (except HH). Larger households dedicating less resources to low yielding varieties fits in with expectations.

Stove ownership (cocina#)

Ownership of a manufactured stove is thought to be a proxy for risk bearing capacity. It also indicates access to consumer goods markets. Households that own a manufactured stove should have higher risk bearing capacity than those who don't, ceteris paribus. We expect this to be correlated to an increased likelihood of the selection of lower yielding and more vulnerable varieties, as well as an increased amount of planting of these varieties. The model results, in table 5.1 show us that this is related to a decrease in the likelihood of selecting Imilla Blanca, a low yielding unimproved variety. In general, the signs of most coefficients on this variable in table 5.3 suggest that stove ownership is correlated with a decrease in the likelihood of selection of most varieties, though only one of these coefficients is significant at the ten percent level (size10, see table 5.1). Stove ownership has positive impacts only for selection of low yielding varieties, but not for all low yielding varieties.

Table 5.2 shows us that ownership of a stove is correlated with increases in the amount planted of Bola Qollyu, Yana Qollyu Rosita, Puca Niawi, Candelero and Pinta Boca potatoes (coefficients on cocina11, cocina8 cocina6 cocina5, cocina4 and cocina3, respectively in table 5.2) . Most of these are low yielding, native unimproved varieties. If stove ownership is a proxy for risk-bearing capacity, we would expect the household to be able to take on more risk, relative to otherwise similar households without a stove. Lower yield and poor performance under adverse conditions could be such a risk. There may also be consumption preferences that are highly correlated with stove ownership (perhaps the ability to prepare potatoes in a certain way that is much more difficult without a stove) that drive the relationship between ownership and these varieties. If we look at the signs of all the coefficients for stove ownership in the second stage, we see that ownership is correlated with larger amounts of plantings in general. The most logical conclusion for this may be that the association between stove ownership and amount planted is connected to wealth, and that wealthy households have more access to the constrained resources necessary for potato production.

Use of hired labor (hired#)

The use of hired labor for potato production is signified by a dummy variable that is equal to 1 if the household reported hiring labor for agricultural activities in the last year. Prior expectations would be that labor access should be correlated with more extensive farming of high yielding varieties, and less of low yielding varieties. Labor market access is associated with an increased likelihood of selection of Qorisongo, according to the positive coefficient on hired7 in table 5.1. Access to hired labor is also correlated with a decreased likelihood of selecting Waych'a, the most common variety in the sample (hired, table 5.1). This may relate to the ease of marketing Waych'a potatoes (they are the most common variety in the market). If on-farm labor can be performed by non-family members, such as hired laborers, this may leave the family with more labor to dedicate to the marketing of other varieties.

Credit use/access (credit#)

Access to credit can have many hypothesized impacts on which varieties a household chooses and how much of each chosen variety are planted. Credit can be used before risky events, to help cover the costs of diversification into activities with low income covariance. If this diversity is applied across potato varieties, we would expect that credit use would be correlated with the purchase of seed of several different varieties, or an increase in the likelihood of selection of varieties. Since this model examines the impact on each variety separately, this relationship may not be present in our results. Credit could also be used after risky events if some activity that the household specializes in had a bad year. For example, if a household is specialized in a variety that is high yielding but blight susceptible, access to credit could help the household recover after a blight epidemic. This would lead us to believe that households that use credit would have a relatively low (compared to other households) capacity to bear risk, since they may have used much of that capacity in the near past and not had the opportunity to restore the capacity. The impact this would have on variety selection is unclear. Recent disaster may instill a desire to pursue a more diversified strategy. Or it may be associated with a decrease in resources that would deter more complicated strategies, such as diversification.

Households who have accessed credit in the last year are much more likely to plant HH (a high yielding, highly blight tolerant variety) represented by the large, positive significant coefficient on credit2 in table 5.1. They are also less likely to select Waych'a, according the negative coefficient on credit in table 5.1. What makes this interesting is that almost half of those who accessed credit and planted HH used kept seed for HH plantings. If this stems from the use of credit after disaster, it has implications for the adoption of this variety. Households that experience disaster may be more likely to adopt the blight tolerant variety in hopes of averting future disaster. This could also be related to the positive coefficient on credit5 in table 5.2, which suggests that households using credit are inclined to plant larger amounts of Puca Niawi, when they select that variety. The fact that so few coefficients on credit are significant may be related to the wide array of possible uses for credit mentioned above.

Weekly market visits (wkly#)

This variable takes the value of one if a household visits the market at least once a week, and equals zero otherwise. Regular market visits imply easy access to inputs, outputs and information. In general, market access is expected to lead to increased commercialization, both from lower costs of inputs and lower marketing costs for output. It should also make it easier for households to find and buy products that they don't produce themselves, leading to less need to grow varieties that are desired strictly for consumption purposes. The results from the model do not confirm these hypotheses, but if we use the ideas behind the hypotheses we can find a reasonable interpretation for the results.

Weekly visits to the market are correlated at a highly significant and large level (wkly3=1.07; wkly2=1.10, table 5.1) with selection of Pinta Boca and HH varieties. It is also positively correlated, though not in a significant (at least 10%) way with selection of varieties 1, 4, 5, 6, 8 and 10).Selection of HH, Rosita (variety 6) and Puca Niawi may be related to better information about their blight tolerant properties available to those who visit markets regularly. Pinta Boca selection could be connected with an increased social role that stems from social contact in the market; it is traditional to serve Pinta Boca potatoes to guests and on some holidays.

Non farm labor market (nflm#)

This is a count variable, representing the number of persons in the household who have employment in the non-farm labor market. Participation in the non-farm labor market reflects household diversification across activities. Like credit use, there are competing hypotheses about how this will impact variety choice. It could be associated with greater risk bearing capacity. Greater risk bearing capacity may ease the burden of planting low yield, vulnerable varieties. It could also signify less access to on-farm labor and from that a need to simplify farm procedures (fewer varieties, less extensive plantings).

What we see from the model is that non-farm labor has little impact on variety selection decisions. There are several coefficients of each sign, and only one is significant at the ten percent level (table 5.3). The varieties that have the same sign on these coefficients do not form any pattern or have any commonality that the author has identified. The one statistically significant result is the positive coefficient on nflm8 in table 5.1, corresponding to Yana Qollyu. In the second stage, where we see the relationship between non-farm labor and the amount planted of individual selected varieties, non-farm labor is correlated with more area planted to most of the varieties. This may mean that, in general, non-farm income is used to supplement farm income and to help accrue cash for investments in expansion of the farm. Access to non-farm labor opportunities may be correlated geographically with ease of access to seed markets, and lower costs for purchasing seed. Household data suggests that labor markets are more accessible from Colomi (see table 4.2, count) than other areas. The level of potato variety diversity in Colomi may also mean an increase in available seed. If access to non-farm labor markets is correlated with access to seed markets, this may explain some of the relationships we see.

Membership in farmer organization (member#)

We expect that membership in farmer organizations will give a household increased access to input markets and to information about varieties. There are no definite prior expectations as to whether this access to information and markets would have a stronger impact on traditional varieties, or improved ones. The uncertainty extends to attempts to hypothesize whether membership would be correlated with diversification or specialization. Membership in local farmer organizations, indicated by a dummy variable, increases the likelihood of selecting several varieties according to coefficients reported in table 5.1 and general impacts in table 5.3. This impact is significant for six varieties (Waych'a, Candelero, Yana Qollyu, Wawilo, Imilla Blanca and Bola Qollyu). It is larger than other selection stage coefficients on other household characteristics for most varieties as well. The only negative correlations we see with membership in the selection stage are on HH and Rosita. Neither of these are statistically significant, but it is interesting to note that these are the two high yielding blight resistant varieties.

Membership has a neutral or negative impact on individual variety levels. If membership is associated with decreased amounts planted of chosen varieties, this suggests that members are more likely to diversify (more varieties and smaller plantings of each) their potato plantings. If membership does give access to local potato seed, this access is correlated with diversification.

Potato as primary crop (primary, prim#)

In the model, we use a dummy variable to indicate that a household listed potato as the most important crop that they grow on the modulo 5 section of the survey. Farmers who do not list potato as their most important crop are more likely to plant several native varieties (Pinta Boca, Candelero and Imilla Blanca) which are vulnerable to risk factors. This is reflected in table 5.1 by the negative coefficients on prim3, prim4 and prim10. These coefficients are large and highly significant, and probably reflect household consumption preferences for native varieties. The selection of traditional varieties could be related to the fact that household's not invested primarily in potatoes may face smaller overall losses due to negative shocks to the potato crop. This may decrease, relative to other households, their level of concern for potato related risks, and encourage them to plant less hearty varieties that have favorable non-production qualities.

Households who grow potato as their primary crop could be expected to dedicate more area to potatoes. Most of the coefficients on the primary variable are positive in the second stage (table 5.3), suggesting that these households do indeed dedicate more resources to potato production than do households with another major crop.

Approximate value of livestock holdings (lstock#)

The variable used in the model to represent livestock holdings is in 1000's of Bolivianos. At the time of the survey, one US dollar was officially worth 7.75 Bs. The value of the variable is based on average values of livestock from PROINPA research and the numbers and types of livestock that each household reported owning during the field survey (Modulo 2, Preguntas1.1-1.12, Encuesta de Variedades de Papa, SANREM CRSP).

Livestock holdings are often considered as a proxy for wealth or risk bearing capacity. They can also reflect income diversification and through that, increased risk bearing capacity. In this model, greater livestock holdings are associated with a decrease in the amount planted of most varieties. The exception to this relationship is Waych'a. If livestock are related to risk mitigation, the relationship with Waych'a could mean that diversification across varieties is a substitute for diversification across assets. Households may invest assets in livestock activities instead of in diversification across potato varieties. As Waych'a is the most commercialized variety, this may represent an investment of gains into non-covariant risk assets, as opposed to investing in more diversified crop production to mitigate risk.

Area (area#)

This continuous variable is the sum for a household of the calculated area planted to each variety that the household plants. It should be noted that this is not just the varieties in the study, but all the plantings that the household described in Modulo 6 in the survey. The area was not used in the second stage of the estimation due to problems of collinearity. We expect that area will be an approximation of risk bearing capacity, and of total investment in potato production. Whether larger farms should be more specialized or more diversified is hard to determine beforehand, and probably relates as much to individual household risk preferences and risk exposures as to anything else. We can say, in general, that households with more area should plant more of chosen varieties, although we were unable to test this hypothesis due to the collinearity issues mentioned above.

Area has a strong, positive relationship with the adoption of HH and Rosita (area2 and area6 coefficients, table 5.1). If area represents risk bearing capacity, this may mean that the market risk of growing an unpopular variety is greater (or more difficult to mitigate) than the agricultural risk of late blight exposure. What we would be seeing, if this is true, is that the households with the greatest risk bearing capacity are more likely to plant the risky varieties, which in this conjecture are the blight resistant ones. Some of this based on the fact that PROINPA has been working on breeding blight resistant varieties with taste and consumption characteristics more like Waych'a (webpage http://www.proinpa.org/adminweb /novedadview.php?id=31; 08/06/08).

5.2 Results and Discussion- Variety Characteristics

The main interest of this project is in the role played by potato variety characteristics in farm-household's potato variety decisions. We had originally hoped to include many variety characteristics in the analysis, but there turned out to be very little differentiation among the varieties for some of these characteristics. Our final analysis looks at the role of a variety's reactions to blight and frost, and to the variety's expected yield as determinants of variety choice and of the amount of selected varieties that are planted. Other measures of productivity under adverse conditions, such as pest tolerance or drought tolerance, exhibited high levels of collinearity with the frost and blight variables. When farmers were polled about their opinions on variety differences in performance under these latter conditions, they rarely expressed a belief that there were differences.

The results for yield are right in line with expectations. Other variety characteristics produced some results that are counter to our original hypotheses. Given the limited nature of our knowledge about some variety attributes and the assumptions required for the model to be accurate, we present some possible explanations for the deviations from our earlier expectations.

Blight resistance

We expect blight resistance to be positively correlated with selection and with planting levels. If two potato varieties are otherwise similar, but one is blight resistant, it seems reasonable to expect that the farm households will prefer the blight resistant variety, all else equal. A variety that is highly blight resistant should be preferred over one that is moderately blight resistant. This is assuming that farmers have knowledge of the variety as a blight resistant variety, and that they have incentive to adopt blight resistant varieties due to exposure to potato late blight. We are also assuming that cost of seed for these varieties is not different than for other varieties.

While our expectations are fairly straightforward, the results are not. Blight resistant potato varieties are less likely to be selected (Blight res. and Blight res-high, table 5.1). There are multiple possible explanations for this. Missing information on plot characteristics may play a large part. Plots that have more moisture may be targeted for blight resistant varieties. There may be some farms that do not have blight problems (although over 90% of farmers reported performing some action to reduce disease[1] problems). Others may not be completely aware of the advantages of blight resistant varieties. This model is based on high levels of information being available about varieties. If that is not the case, ignorance of blight resistant varieties may be a large barrier to more extensive adoption. There may also be disadvantages unrelated to production. It is unclear whether HH is heavily marketed or not; PROINPA market records are limited, but show less observations of HH in the market than of Waych'a or Puca Niawi (Precios Ferias, Amaya). Market acceptance should be related to consumption preferences, so these together may have a role in the infrequency of selection.

Once blight resistant varieties are selected, they are planted at greater levels than susceptible varieties (all else equal). Interesting to note, the expectation that highly resistant varieties would be more extensively planted than moderately resistant ones is not true. The coefficient on high resistance is actually smaller (though not by much, table 5.2), and less statistically significant than the coefficient on moderate resistance. Again, it is important to remember that a lot of information is missing from this model, particularly about different levels of risk exposure due to climatic/geographic features, that might change the relationship between these two categories of potato varieties (moderately blight resistant and highly blight resistant).

Frost tolerance and susceptibility

Like blight resistance, our expectations of frost tolerance are straightforward. Varieties that are frost tolerant should be more likely to be selected, and should be planted in greater area when selected. Also like blight resistance, the results that this model gives us are not completely in line with our expectations. Again, we look for problems and shortcomings in our assumptions and data for the reasons for these unexpected results

---

[1] The survey form refers to 'enfermedeades' at this point, but this was often translated as 'toctu', the quechua word for late blight, by enumerators.

Frost tolerance has uneven impacts on the variety choice process. The coefficient on the 'frost tolerance' dummy variable is not statistically significant in either the selection (table 5.1) or levels stage (table 5.2). The sign in the first stage is positive as we would expect, but the sign on the coefficient in the levels stage is negative. Again, we have concerns about access to information (whether or not farmers know of the advantages of these varieties), market/consumption characteristics that may coincide, or the possibility of lack of exposure to the risk factor (lack of concern about frost). Geographic features of individual plots may also impact frost risk exposure, and not all individual plots may be exposed to frost risk. Frost is more likely to form at the bottom of valleys, and may be correlated with other plot characteristics (surrounding vegetation, tree cover, etc.) that are not measured in this survey.

When we turn to frost susceptibility, we expect the coefficients in both stages of the model to be negative; if a variety is more susceptible to frost damage, it should be less desirable to select, and less scarce resources should be invested in it if selected. This is true for the second stage (table 5.2) but not the first, noted by the positive coefficient in table 5.1. These coefficients are not significant at traditional levels, but that on selection, is significant at the 15% level. To include the coefficient from the levels model, we would have to extend our significance consideration to a 20% margin. These coefficients are both larger than the ones on frost tolerance, but smaller than those on blight resistance. The unexpected selection impact may be indicative of other characteristics that are correlated with frost susceptibility that are not measured in this model. It may be possible that frost susceptible varieties do not represent an increase in risk exposure to most farmers.

Expected Yield

Expected yield should be an important determinant of how much of a constrained resource, such as land or labor, will be allocated to an individual potato variety. We expect the coefficients on these variables to be positive and to represent a large incentive to select and to increase plantings when moving from a low yielding variety to a high yielding variety. Table 5.2 shows us that this is the case, and that expected yield is an important determinant of the amount of chosen varieties that households plant.

5.3 Potential Problems and consequences

Any analysis like this has potential problems. In this case there are two in particular that are worth mentioning. The first possible problem involves the sample selection. It is possible, given the limited information that was available to design the selection/sampling process, that the sample included is not random. This would call into question much of the inference included in this analysis. The inference is based on the idea that the households surveyed are selected at random, and that there is not some criteria by which those sampled differ from the population in a significant way. We believe that the data represent a random sample of the communities surveyed, but without more information it is hard to say how far the inference in this paper can be extended beyond those communities.

Another aspect that might decrease the accuracy of this study is the possibility that households select a portfolio of varieties to minimize their risk exposure/maximize their outcomes according to subjective probability measures. If this is the case, varieties may be selected in pairs or combinations and not independently as is assumed here. This would have a large impact on the selection stage, and through that would be the source of bias in the second stage.

The biggest problem with this project is the lack of data on additional variables that would be of interest. Consumption preferences, marketing characteristics, accurate details about individual potato plots, meteorological factors, etc. would all help to focus the study and allow for more robust analysis. The current project is viewed as a reasonable effort in light of these limitations. That said, a similar analysis that was able to include such data could be of extreme interest.

Table 5.1 Significant Coefficients of the First Stage of the model (selection of varieties)

Variable	Coefficient	Std Dev	Significance level
Frost suscept.	0.55	0.97	(p=.571)
Frost tolerance	0.17	0.75	(p=.823)
Blight res.	-1.67	0.89	10%
Blight res.-High	-1.81	0.83	5%
size11	-0.14	0.08	10%
size10	-0.23	0.08	1%
size8	-0.13	0.06	5%
cocina10	-1.32	0.42	1%
area10	1.47	0.59	5%
area9	-0.41	0.24	10%
area6	1.24	0.27	1%
area2	1.17	0.55	5%
lstock11	0.02	0.01	5%
credit2	1.36	0.51	1%
credit	-0.37	0.23	10%
wkly3	0.9	0.38	5%
wkly2	0.69	0.31	5%
hired7	0.57	0.33	10%
hired	-0.31	0.18	10%
member11	0.72	0.27	1%
member10	0.68	0.36	10%
member9	1.29	0.37	1%
member8	1.53	0.31	1%
member4	0.68	0.35	10%
member	0.52	0.2	1%
nflm8	0.44	0.25	10%
prim10	-0.83	0.47	10%
prim9	1	0.5	5%
prim4	-1.16	0.68	10%
prim3	-1.2	0.66	10%

Table 5.2 Significant Coefficients of Second Stage of Model (planting levels as a function of variety and household characteristics)

Variable	Coefficient	Std Dev	Significance level
log(yield)	1.3	0.28	1%
Frost suscept.	-1.33	0.93	(p=.152)
Frost tolerance	-0.75	0.62	(p=.228)
Blight res.	1.3	0.96	(p=.175)
Blight res.-High	1.23	0.86	(p=.155)
size10	-0.44	0.15	1%
size8	-0.24	0.06	1%
size7	-0.21	0.09	5%
size5	-0.14	0.07	5%
size2	-0.16	0.09	10%
cocina11	2.47	1.06	5%
cocina8	-0.56	0.33	10%
cocina6	0.79	0.35	5%
cocina5	0.62	0.3	5%
cocina4	0.68	0.29	5%
cocina3	0.64	0.3	5%
lstock11	-0.09	0.03	1%
lstock9	-0.06	0.03	5%
lstock8	-0.14	0.03	1%
lstock4	-0.03	0.02	10%
lstock3	-0.06	0.02	1%
lstock	0.01	0.01	10%
credit5	0.56	0.32	10%
wkly8	1.06	0.47	5%
wkly6	-0.76	0.44	10%
hired11	-1.79	0.76	5%
hired10	1.71	0.45	1%
member11	-1.74	1.03	10%
member10	-1.42	0.48	1%
member4	-0.68	0.32	5%
nflm8	0.52	0.12	1%
nflm6	-0.27	0.15	10%
prim10	2.61	0.51	1%

Table 5.3- Signs and Significance of Coefficients, Summary

Stage 1 (selection)

hh variable	1	2	3	4	5	6	7	8	9	10	11
	variety index#										
size	+	+	-	-	+	+	+	-**	-	-***	-*
cocina	-	-	+	-	-	-	-	+	-	-***	+
area	+	+**	+	+	+	+***	+	-	-*	+**	-
lstock	+	-	+	+	-	-	+	-	-	+	+*
credit	-*	+***	-	-	-	-	-	-	-	/	+
wkly	+	+**	+**	+	+	+	-	+	-	+	/
hired	-*	-	-	+	+	-	+*	+	-	-	+
member	+***	-	+	+*	+	-	+	+***	+***	+*	+***
nflm	+	-	-	-	+	+	-	+*	+	/	-

Stage 2 (amount planted of selected variety)

hh variable	1	2	3	4	5	6	7	8	9	10	11
	variety index#										
size	-	-**	-	-	-**	+	-**	-***	+	-***	+
cocina	+	+	+**	+**	+**	+**	+	-**	+	+	+**
lstock	+*	-	-***	-*	+	-	+	-***	-**	+	-***
credit	+	-	-	-	+*	-	-	-	+	/	-
wkly	+	+	-	-	+	-*	+	+**	+	-	/
hired	+	-	-	-	-	+	-	-	-	+***	-**
member	-	+	+	-**	-	+	-	+	-	-***	-*
nflm	+	+	+	+	+	-*	+	+***	-	/	-
prim	+	+	-	+	-	-	+	/	-	+***	+

Note: *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively

The role of consumption preferences is not modeled in this study. It is expected that these preferences play a large role in the potato variety decisions, but the author does not know of a reliable way to measure consumption preferences. Price can be a good approximation, but supply concerns may complicate this; less favored varieties may have smaller supplies and therefore a disproportionately high price. Similar studies ask farm households to evaluate each variety during the field survey. Edmeades and Smale (2005) for example, ask farm households to rate the cooking quality of banana varieties according to the following scale: 1=bad; 2=neither good nor bad; 3=good. The average values of this variable on the varieties used in their paper range from 2.82 to 2.97. Five of the seven are grouped between 2.88 and 2.93, which would be identical if carried out to one less significant digit (this would still be one more digit than is present in the source). When dealing with semi-subsistence crops, such as potatoes in Bolivia or bananas in

Uganda, it is logical to conclude that the varieties that are commonly planted are all considered suitable for consumption. Gradations beyond this are very difficult, and beyond the scope of this paper.

Assumptions that are made include that prices paid for seed material and profit expected from potato sales are not different across varieties. More information on this would increase the power of the model. Additional information and variation on agro-ecological conditions, and a larger sample would also lend credence to the inferences made here.

6. Conclusions and areas for continued research

Consumption preferences and market forces play a large role in potato variety selection in Bolivia. Agro-climatic risk management and variety risk performance attributes also play a role in planting decisions. It is clear that more risk management could be accomplished through variety selection, although it is not clear whether or not breeding (to develop new varieties that incorporate desirable risk characteristics) is the best way to accomplish this. It may be possible to more aggressively market existing varieties with desirable production characteristics. The results of this study, that blight resistant varieties are less likely to be selected by farm households than other varieties, leads us to believe that there are market and/or consumption preferences against the blight resistant varieties.

We are also led to the conclusion that the risks of the market, probably represented by low profits, are either of greater concern or else more difficult to mitigate with methods other than variety selection than the risks posed by late blight. The market acceptance of blight resistant varieties should be investigated, both for potential sale of these varieties and for the possibility of breeding these with frost tolerant native varieties. PROINPA has been involved in breeding efforts to develop a Waych'a derivative that is blight resistant, although tests of the resulting varieties (Libertad, Anita, Aurora) suggest that they may not be as desirable for consumption as the original Waych'a (webpage http://www.proinpa.org/adminweb /novedadview.php?id=31; 08/06/08). This desire to breed a blight resistant variety with taste similar to Waych'a suggests that existing blight resistant varieties may not be easy to market, or at least not as easy as Waych'a. This difficult marketing situation would be a reasonable explanation for farmer's reluctance to adopt the blight resistant varieties. Further tests of these new varieties in terms of market acceptance will be of great interest.

Lack of access to information about the blight resistant varieties is another potential barrier that should be investigated. Unless the blight tolerant varieties have horrible consumption attributes that no other varieties have, the decrease in selection likelihood is hard to explain. The magnitude and significance of the coefficients in table 5.1 on blight resistance combined with the positive coefficients in table 5.2 on the same suggest that a definite barrier exists. Whether this is due to lack knowledge about the varieties, lack of access to seed or to some unmeasured attribute co-incident with blight resistance we don't know. Finding out more about this, about why farmers are less likely to adopt these but tend to plant in larger areas when they do could help identify needs for breeding programs and for extension service. The observation in chapter 5 about a connection between membership in farmer organizations and non-adoption of the high yielding blight resistant varieties may be an indicator of a good starting point for such research. If the farmer organizations do have a reason to avoid HH and Rosita, it may be possible to target breeding programs at this reason. Involving these farmer organizations in participatory breeding programs would be a good step towards ensuring wider adoption of new varieties.

The correlation between credit use and adoption of the blight resistant variety HH is another factor that should not be overlooked. This result, the increased tendency of households who use credit to also plant this high yielding, blight resistant variety, may mean that exposure to disastrous blight infestations is a major reason that households will adopt the variety. It could also be related to the cost of seed material for HH, but the fact that only half of the households that exhibit credit use and HH plantings bought seed material for this variety (as opposed to having saved it from the previous year) suggests that this would only be a partial explanation. The fact that only this variety exhibited such a relationship with credit use makes interpretation of this result more difficult. It suggests that there must be some attribute that we have not measured here that HH has in a high level. This attribute could be related to public opinion or to information available to farmers. More information about the differences between HH and Rosita, which seem similar, may help to elaborate the reasons why this relationship between HH and credit exists, and may shed light on the case of blight resistant varieties in general.

There is no factor in this study that clearly explains why Waych'a is as common as it is. The few discussions the author had in Bolivia relating to this suggested that Waych'a is grown because it is what buyers in and from the city want. Discussions with consumers, though limited, did not reveal any inherent preference for Waych'a over other varieties. It most likely represents a good compromise. The only real drawback is that it is not blight resistant. More information about blight incidence on Waych'a plantings, including methods of control, would be of great interest. It may be that fungicides can adequately control blight on Waych'a. In this case, breeding represents a good chance to decrease use of agrochemicals. It could also decrease costs for farmers, particularly the more remote households, who would not need to spend cash income on agrochemicals. Decreasing use of agrochemicals and production costs, while maintaining welfare, is always desirable.

Prevalence of one variety may ease marketing for intermediaries if they prefer to deal in a homogenous product. If this is the case, it may be possible to substitute other varieties for Waych'a. Most higher yielding blight resistant varieties are susceptible to frost, which may not be ideal, but breeding these varieties for frost tolerance may be as feasible as breeding Waych'a for blight resistance and higher yield. This would depend on marketability of the finished product. It would also be beneficial to have a clear picture of the effectiveness and impacts of methods used (leaf fertilizers and straw cover) by farmers to protect crops from frost.

About 60% of expected potato harvests in this study are intended for market, and about 30% are intended for the table (the final 10% are for seed for the next year). Planting decisions for these two are not separate. Information on consumption preferences and market prices should be able to contribute to the knowledge gained in this study. PROINPA has undertaken some price tracking, but the limited picture they were able to collect in the market is far from complete. Right now they have a record from several markets for one year. Many varieties that are encountered in the current study are not represented in the PROINPA price data. This may be because varieties are not marketed. It may also relate to how varieties are marketed; if they are sold to intermediaries direct from the farm and then go to the city or a supermarket, these prices would not be observed in the rural 'ferias', which is where the existing information was collected.

Theoretically, price and consumption preferences should correspond (for marketed varieties, at least). The impact of expected price should help to identify further motivations of potato variety choice. Price will also be subject to supply concerns, although without the underlying desire for the products, expressed by consumption preferences, shortness of supply alone can not make something desirable. It may be that price itself is not as important a determinant as ‘expected gain’, which should include input and output prices as well as labor costs related to production and marketing. The dual nature of semi-subsistence farm households as both producers and consumers of the same goods make the interaction between supply and demand issues harder to interpret. Of course, more detailed information on price could only help this situation. Gathering information on input and output prices, as well as other market information, is a task that would benefit all research on farm households in this region.

Bolivian farmers face many challenges to increasing the level of well being in their communities. This study has begun to investigate the strategies used to overcome these, and by doing so has provided an increased understanding necessary for planning more efficient strategies. Variety selection and breeding is an important tool for managing agricultural risk in a sustainable fashion. Continued work on breeding, distributing and marketing new and alternative varieties of potato can help farmers face challenges and increase the income of farmers, and through that channel help develop more diversified rural economies.

Bibliography

Amemiya, Takeshi. 1985. *Advanced Econometrics* Cambridge MA: Harvard University Press

Benin, S., M. Smale, J. Pender, B. Gebremedhin and S. Ehui. 2004. "The economic determinants of cereal crop diversity on farms in the Ethiopian highlands" *Agricultural Economics* 31:197-208

Brush, Stephen B., J. Edward Taylor and Mauricio Bellon. 1992. "Technology adoption and biological diversity in Andean potato agriculture" *Journal of Development Economics* 39:365-387

Cameron, A. Colin and Pravin K. Trivedi. 2005. *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Chambers, Robert G. and John Quiggin. 2000 *Uncertainty, Production, Choice and Agency: The State Contingent Approach.* Cambridge MA: Cambridge University Press

Dalton, Timothy J. 2004. "A household hedonic model of rice traits: economic values form farmers in West Africa" *Agricultural Economics* 31:149-159

DiFalco, Salvatore, Jean-Paul Chavas and Melinda Smale. 2007. "Farmer management of production risk on degraded lands: the role of wheat variety diversity in the Tigray region, Ethiopia" *Agricultural Economics* 36:147-156

Edmeades, Svetlana and Melinda Smale. 2006. "A trait-based model of the potential demand for a genetically engineered food crop in a developing economy" *Agricultural Economics* 35:351-361

Feder, Gershon, Richard E. Just and David Zilberman. 1985. "Adoption of agricultural innovations in developing countries: a study" *Economic Development and Cultural Change* 33(2):255-298

Fundacion PROINPA and Asociación de Productores de Tubérculos Andinos. 2004. *Catalogo de Variedades Locales de Papa y Oca de la Zona de Candelaria* Cochabamba, Bolivia

Hagigi, Moshe and Brian Kluger 1986. "Safety First: An alternative performance measure" *Journal of Portfolio Management* Summer:34-40

Heckman, James J. 1979. "Sample Selection Bias as a Specification Error" *Econometrica* 47(1):153-161

Hijmans, R. J., B. Condori, R. Carrillo and M. J. Kropff 2003. "A quantitative and constraint specific method to assess the potential impact of new agricultural technology:

the case of frost resistant potato for the Altiplano (Bolivia and Peru)" *Agricultural Systems* 76:895-911

Hintze, L. H., M. Renkow and G. Sain 2003. "Variety characteristics and maize adoption in Honduras" *Agricultural Economics* 29:307-317

Pender, John and Peter Hazell. 2000. "Promoting sustainable development in lass favored areas" *2020 Vision Focus 4* Washington, DC: International Food Policy Research Institute.

Shively, Gerald. 2000. "Soil conservation and consumption risk in a model of low income agriculture" *Environmental Monitoring and Assessment* 62:55-69

-1997. "Consumption risk, farm characteristics and soil conservation adoption among low income farmers in the Philippines" *Agricultural Economics* 17:165-177

Smale, Melinda, Richard E. Just and Howard D. Leathers 1994. "Land Allocation In HYV Adoption Models: An Investigation of Alternative Explanations" *American Journal of Agricultural Economics* 76:535-546

Smale, Melinda and Hugo DeGroote. 2003. "Diagnostic research to enable adoption of transgenic crop varieties by smallholder farmers in sub-Saharan Africa" *African Journal of Biotechnology* 2(12):586-595

Tadesse, Dawit and Steven C. Blank. 2003. "Cultivar diversity: a neglected risk management strategy" *Journal of Agricultural and Resource Economics* 28(2) 217-232

Terrazas, F., V. Suarez, G. Gardner, G. Thiele, A. Devaux and T. Walker. 1998 "Diagnosing Potato Productivity in Farmer's Fields in Bolivia" Working paper, Social Science Department, International Potato Center

Thiele, G., G. Gardner, R, Torrez and J. Gabriel. 1997. "Farmer involvement in selecting new varieties: Potatoes in Bolivia" *Expl Agric.* 33:275-290

Train, Kenneth E. 2003 *Discrete Choice Methods with Simulation.* Cambridge MA:Cambridge University Press

von Haefen, Roger H., Daniel J. Phaneuf and George R. Parsons. 2004. "Estimation and Welfare Analysis with Large Demand Systems" *Journal of Business and Economic Statistics* 22(2):194-205

Walker, T. S., Y. P. Bi, J. H. Li, P. C. Gaur and E. Grande. 2003. "Potato Genetic Improvement in Developing Countries and CIP's Role in Varietal Change" In R. E. Evenson and D. Gollin, Eds. *Crop Variety Improvement and its Effect on Productivity* Cambridge MA: CABI Publishing, pp. 315-336

Appendix 1- Code and output from Stata

```
-------------------------------------------------------------------------------
       log:  C:\DATA\tue5.smcl
  log type:  smcl
 opened on:   5 Aug 2008, 11:36:54

. heckman lv ly fa fc bc bd size11 size10 size9 size8 size7 size6 size5 size4 siz
> e3 size2 size cocina11 cocina10 cocina9 cocina8 cocina7 cocina6 cocina5 cocina4
>   cocina3 cocina2 cocina hired11 hired10 hired9 hired8 hired7 hired6 hired5 hir
> ed4 hired3 hired2 hired credit11 credit9 credit8 credit7 credit6 credit5 credit
> 4 credit3 credit2 credit wkly10 wkly9 wkly8 wkly7 wkly5 wkly4 wkly3 wkly2 weekl
> y wkly6 nflm11 nflm9 nflm8 nflm7 nflm6 nflm5 nflm4 nflm3 nflm2 nflm member11 me
> mber10 member9 member8 member7 member6 member5 member4 member3
member2 member p
> rim11 prim10 prim9 prim8 prim7 prim6 prim5 prim4 prim3 prim2 primary  lstock ls
> tock2 lstock3 lstock4 lstock5 lstock6 lstock7 lstock8 lstock9 lstock10 lstock11
> , select(wkly10 wkly9 wkly8 wkly7 wkly5 wkly4 wkly3 wkly2 weekly wkly6 nflm11 n
> flm9 nflm8 nflm7 nflm6 nflm5 nflm4 nflm3 nflm2 nflm credit11 credit9 credit8 cr
> edit7 credit6 credit5 credit4 credit3 credit2 credit size11 size10 size9 size8
> size7 size6 size5 size4 size3 size2 size cocina11 cocina10 cocina9 cocina8 coci
> na7 cocina6 cocina5 cocina4 cocina3 cocina2 cocina hired11 hired10 hired9 hired
> 8 hired7 hired6 hired5 hired4 hired3 hired2 hired member11 member10 member9
mem
> ber8 member7 member6 member5 member4 member3 member2 member prim11
prim10 prim9
>  prim8 prim7 prim6 prim5 prim4 prim3 prim2 primary lstock lstock2 lstock3 lstoc
> k4 lstock5 lstock6 lstock7 lstock8 lstock9 lstock10 lstock11 fa fc bc bd) diffi
> cult cluster(hhid)
note: prim8 dropped due to collinearity

Iteration 0:   log pseudo-likelihood = -1162.8057  (not concave)
Iteration 1:   log pseudo-likelihood = -1106.2278  (not concave)
Iteration 2:   log pseudo-likelihood = -1097.1179  (not concave)
Iteration 3:   log pseudo-likelihood = -1071.6559  (not concave)
Iteration 4:   log pseudo-likelihood = -1019.7362  (not concave)
Iteration 5:   log pseudo-likelihood = -949.13118  (not concave)
Iteration 6:   log pseudo-likelihood = -920.20282  (not concave)
Iteration 7:   log pseudo-likelihood = -917.44583  (not concave)
Iteration 8:   log pseudo-likelihood = -908.92031  (not concave)
Iteration 9:   log pseudo-likelihood = -898.78687
Iteration 10:  log pseudo-likelihood = -888.36544
Iteration 11:  log pseudo-likelihood = -882.53233  (backed up)
Iteration 12:  log pseudo-likelihood = -880.02758  (not concave)
Iteration 13:  log pseudo-likelihood = -871.05421
Iteration 14:  log pseudo-likelihood = -869.43653
Iteration 15:  log pseudo-likelihood = -867.54079
Iteration 16:  log pseudo-likelihood = -864.24358
Iteration 17:  log pseudo-likelihood = -862.99734
Iteration 18:  log pseudo-likelihood =  -861.7363  (not concave)
```

```
Iteration 19:  log pseudo-likelihood =  -861.2836
Iteration 20:  log pseudo-likelihood = -860.75999
Iteration 21:  log pseudo-likelihood = -860.60791
Iteration 22:  log pseudo-likelihood = -860.57491
Iteration 23:  log pseudo-likelihood =  -860.3441
Iteration 24:  log pseudo-likelihood = -860.13753  (not concave)
Iteration 25:  log pseudo-likelihood = -860.03521
Iteration 26:  log pseudo-likelihood = -859.93963
Iteration 27:  log pseudo-likelihood = -859.83302  (not concave)
Iteration 28:  log pseudo-likelihood =  -859.7613
Iteration 29:  log pseudo-likelihood = -859.72721
Iteration 30:  log pseudo-likelihood = -859.69297
Iteration 31:  log pseudo-likelihood = -859.69126
Iteration 32:  log pseudo-likelihood = -859.69101  (backed up)
Iteration 33:  log pseudo-likelihood = -859.68996  (backed up)
Iteration 34:  log pseudo-likelihood = -859.67648
Iteration 35:  log pseudo-likelihood = -859.65401
Iteration 36:  log pseudo-likelihood = -859.65392  (backed up)
Iteration 37:  log pseudo-likelihood = -859.65371  (backed up)
Iteration 38:  log pseudo-likelihood = -859.64994
Iteration 39:  log pseudo-likelihood = -859.64422  (not concave)
Iteration 40:  log pseudo-likelihood = -859.63954
Iteration 41:  log pseudo-likelihood = -859.63618  (not concave)
Iteration 42:  log pseudo-likelihood = -859.63509
Iteration 43:  log pseudo-likelihood = -859.63291
Iteration 44:  log pseudo-likelihood = -859.63122
Iteration 45:  log pseudo-likelihood = -859.62961  (not concave)
Iteration 46:  log pseudo-likelihood = -859.62905
Iteration 47:  log pseudo-likelihood = -859.62824
Iteration 48:  log pseudo-likelihood = -859.62755
Iteration 49:  log pseudo-likelihood = -859.62675  (not concave)
Iteration 50:  log pseudo-likelihood = -859.62655

Heckman selection model                       Number of obs      =       990
(regression model with sample selection)        Censored obs       =       592
                                              Uncensored obs     =       398

                                              Wald chi2(18)      =         .
Log pseudo-likelihood = -859.6266               Prob > chi2        =         .

                         (standard errors adjusted for clustering on hhid)
------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lv           |
          ly |   1.529587   .3275228     4.67   0.000     .8876539     2.17152
          fa |  -1.470733   1.098215    -1.34   0.181    -3.623195    .6817287
          fc |  -.4626384   .6433175    -0.72   0.472    -1.723517    .7982407
          bc |   1.786544   .9205441     1.94   0.052    -.0176891    3.590778
          bd |   1.344037   .8776348     1.53   0.126    -.3760951     3.06417
```

size11	.131822	.0942037	1.40	0.162	-.0528139	.3164579
size10	-.4928872	.0668407	-7.37	0.000	-.6238925	-.3618818
size9	.0010496	.2684904	0.00	0.997	-.5251819	.5272811
size8	-.2109049	.0679917	-3.10	0.002	-.3441661	-.0776436
size7	-.2017844	.1024119	-1.97	0.049	-.4025081	-.0010608
size6	.0807707	.0644595	1.25	0.210	-.0455677	.207109
size5	-.1570053	.0681005	-2.31	0.021	-.2904798	-.0235307
size4	.0079198	.0946741	0.08	0.933	-.1776381	.1934776
size3	.008138	.1189005	0.07	0.945	-.2249027	.2411787
size2	-.2124884	.0853253	-2.49	0.013	-.379723	-.0452538
size	-.0420234	.0483856	-0.87	0.385	-.1368574	.0528106
cocina11	1.786219	.3529813	5.06	0.000	1.094388	2.478049
cocina10	.8619389	.3963679	2.17	0.030	.0850721	1.638806
cocina9	.5042456	.6415579	0.79	0.432	-.7531847	1.761676
cocina8	-.6069905	.3391514	-1.79	0.073	-1.271715	.0577339
cocina7	.1039571	.4223849	0.25	0.806	-.7239021	.9318163
cocina6	.9019872	.5230002	1.72	0.085	-.1230743	1.927049
cocina5	.6003981	.3145839	1.91	0.056	-.0161749	1.216971
cocina4	.5877961	.3105869	1.89	0.058	-.020943	1.196535
cocina3	.6996111	.2707385	2.58	0.010	.1689734	1.230249
cocina2	.1623309	.308224	0.53	0.598	-.4417771	.7664389
cocina	.2192224	.153494	1.43	0.153	-.0816203	.5200651
hired11	-1.167642	.3607287	-3.24	0.001	-1.874657	-.4606268
hired10	1.287971	.4129085	3.12	0.002	.4786853	2.097257
hired9	-.0546117	1.022026	-0.05	0.957	-2.057746	1.948523
hired8	-.2844628	.3455129	-0.82	0.410	-.9616557	.39273
hired7	-.1901617	.3427926	-0.55	0.579	-.8620229	.4816995
hired6	.405667	.7269848	0.56	0.577	-1.019197	1.830531
hired5	-.4255495	.3553442	-1.20	0.231	-1.122011	.2709124
hired4	-.5577076	.377814	-1.48	0.140	-1.298209	.1827942
hired3	-.1483091	.390876	-0.38	0.704	-.914412	.6177938
hired2	-.261697	.3001234	-0.87	0.383	-.849928	.326534
hired	.377163	.1763616	2.14	0.032	.0315006	.7228253
credit11	-.4884991	.4850825	-1.01	0.314	-1.439243	.4622452
credit9	.1444051	.8097392	0.18	0.858	-1.442654	1.731465
credit8	-.5613473	.446737	-1.26	0.209	-1.436936	.3142411
credit7	.3465643	.5200558	0.67	0.505	-.6727264	1.365855
credit6	-.1693342	.681551	-0.25	0.804	-1.50515	1.166481
credit5	.5779906	.341987	1.69	0.091	-.0922917	1.248273
credit4	-.1941568	.3694445	-0.53	0.599	-.9182548	.5299412
credit3	-.2958101	.3915747	-0.76	0.450	-1.063282	.4716622
credit2	-.1886298	.4018518	-0.47	0.639	-.9762449	.5989853
credit	-.0639304	.2565696	-0.25	0.803	-.5667976	.4389368
wkly10	1.388657	.4880335	2.85	0.004	.4321292	2.345185
wkly9	.7597515	.9556038	0.80	0.427	-1.113198	2.632701
wkly8	1.056582	.4991142	2.12	0.034	.0783361	2.034828
wkly7	.0514487	.5257484	0.10	0.922	-.9789992	1.081897
wkly5	.2832383	.4357935	0.65	0.516	-.5709012	1.137378
wkly4	-.0080049	.582	-0.01	0.989	-1.148704	1.132694
wkly3	-.1102224	.4424535	-0.25	0.803	-.9774152	.7569705
wkly2	.4024512	.419732	0.96	0.338	-.4202085	1.225111

weekly	.1612984	.1761341	0.92	0.360	-.183918	.5065148
wkly6	-1.408332	.6577632	-2.14	0.032	-2.697524	-.1191401
nflm11	-1.850066	.9630075	-1.92	0.055	-3.737526	.0373945
nflm9	.1027699	1.003346	0.10	0.918	-1.863753	2.069292
nflm8	.4902143	.1308968	3.75	0.000	.2336614	.7467673
nflm7	.1832601	.1910342	0.96	0.337	-.1911599	.5576802
nflm6	-.4600573	.1689111	-2.72	0.006	-.7911171	-.1289976
nflm5	.0200698	.1246789	0.16	0.872	-.2242963	.2644358
nflm4	.1354513	.5401729	0.25	0.802	-.923268	1.194171
nflm3	.204993	.2074313	0.99	0.323	-.2015647	.6115508
nflm2	.1612553	.1508604	1.07	0.285	-.1344257	.4569362
nflm	.0379822	.0940704	0.40	0.686	-.1463923	.2223568
member11	-2.477557	.9201078	-2.69	0.007	-4.280935	-.6741785
member10	-2.181395	.3685205	-5.92	0.000	-2.903682	-1.459108
member9	-.7574042	.6223562	-1.22	0.224	-1.9772	.4623916
member8	.7420088	.9790538	0.76	0.449	-1.176901	2.660919
member7	-.2357367	.4156456	-0.57	0.571	-1.050387	.5789138
member6	.5547902	.587035	0.95	0.345	-.5957773	1.705358
member5	-.211003	.3297089	-0.64	0.522	-.8572206	.4352147
member4	-.661294	.413545	-1.60	0.110	-1.471827	.1492394
member3	.293091	.4380824	0.67	0.503	-.5655349	1.151717
member2	.1980143	.3080918	0.64	0.520	-.4058345	.8018632
member	-.3837902	.225672	-1.70	0.089	-.8260993	.0585189
prim11	.481764	.3958494	1.22	0.224	-.2940865	1.257614
prim10	2.950579	.3906585	7.55	0.000	2.184903	3.716256
prim9	-1.629731	1.817963	-0.90	0.370	-5.192873	1.933412
prim7	-.0030363	.6581577	-0.00	0.996	-1.293002	1.286929
prim6	-.4900792	.5507581	-0.89	0.374	-1.569545	.5893868
prim5	-1.399146	.7937663	-1.76	0.078	-2.954899	.1566078
prim4	.6246768	.3618131	1.73	0.084	-.0844639	1.333818
prim3	-.0671069	.4649966	-0.14	0.885	-.9784836	.8442698
prim2	.8660785	.3840181	2.26	0.024	.113417	1.61874
primary	.3133745	.5420487	0.58	0.563	-.7490214	1.37577
lstock	.0108609	.0087705	1.24	0.216	-.006329	.0280509
lstock2	-.0310631	.0202415	-1.53	0.125	-.0707357	.0086096
lstock3	-.0644565	.0228482	-2.82	0.005	-.1092381	-.0196749
lstock4	-.03661	.0160653	-2.28	0.023	-.0680975	-.0051225
lstock5	-.0011007	.0345541	-0.03	0.975	-.0688256	.0666242
lstock6	-.030524	.0382957	-0.80	0.425	-.1055821	.0445341
lstock7	.009909	.023402	0.42	0.672	-.0359581	.0557761
lstock8	-.151014	.0265351	-5.69	0.000	-.2030218	-.0990062
lstock9	-.0540779	.0271503	-1.99	0.046	-.1072914	-.0008643
lstock10	-.0225536	.0193285	-1.17	0.243	-.0604366	.0153295
lstock11	-.0687295	.0152573	-4.50	0.000	-.0986334	-.0388257
_cons	-4.771252	.7517891	-6.35	0.000	-6.244731	-3.297772
-------------+--						
select						
wkly10	.3696089	.4336555	0.85	0.394	-.4803403	1.219558
wkly9	-.1720032	.3874383	-0.44	0.657	-.9313683	.5873618
wkly8	.4309589	.3688435	1.17	0.243	-.291961	1.153879
wkly7	-.59413	.4540565	-1.31	0.191	-1.484064	.2958044

wkly5	.4658681	.3754835	1.24	0.215	-.270066	1.201802
wkly4	.3279098	.4044366	0.81	0.417	-.4647713	1.120591
wkly3	1.067212	.3641675	2.93	0.003	.3534564	1.780967
wkly2	1.099667	.290869	3.78	0.000	.5295746	1.66976
weekly	-.339251	.227322	-1.49	0.136	-.7847938	.1062919
wkly6	-.051027	.4308143	-0.12	0.906	-.8954075	.7933534
nflm11	-.2961676	.3282149	-0.90	0.367	-.9394569	.3471217
nflm9	-.006377	.1441225	-0.04	0.965	-.2888519	.2760979
nflm8	.4025014	.2519622	1.60	0.110	-.0913354	.8963383
nflm7	-.3387937	.1550837	-2.18	0.029	-.642752	-.0348353
nflm6	.2882517	.1718973	1.68	0.094	-.0486609	.6251643
nflm5	.004159	.1120357	0.04	0.970	-.2154269	.223745
nflm4	.041445	.1379172	0.30	0.764	-.2288678	.3117578
nflm3	-.0393998	.168154	-0.23	0.815	-.3689756	.290176
nflm2	-.1977565	.2260649	-0.87	0.382	-.6408355	.2453225
nflm	-.0085214	.1789228	-0.05	0.962	-.3592037	.3421608
credit11	.6845074	.4280881	1.60	0.110	-.1545297	1.523545
credit9	-.1750834	.3633557	-0.48	0.630	-.8872476	.5370808
credit8	-.2971175	.3998036	-0.74	0.457	-1.080718	.4864832
credit7	-.1231278	.3540019	-0.35	0.728	-.8169589	.5707032
credit6	-.1162277	.4145913	-0.28	0.779	-.9288118	.6963564
credit5	-.1203784	.3024006	-0.40	0.691	-.7130728	.4723159
credit4	-.6132299	.295686	-2.07	0.038	-1.192764	-.033696
credit3	-.2672604	.3654282	-0.73	0.465	-.9834866	.4489658
credit2	2.06889	.3521079	5.88	0.000	1.378771	2.759009
credit	-.5348787	.2404536	-2.22	0.026	-1.006159	-.0635984
size11	-.1584393	.0833304	-1.90	0.057	-.3217638	.0048853
size10	-.1725698	.0596334	-2.89	0.004	-.2894491	-.0556906
size9	-.0773795	.0678532	-1.14	0.254	-.2103693	.0556104
size8	-.1394035	.0589526	-2.36	0.018	-.2549484	-.0238586
size7	.1832529	.0743377	2.47	0.014	.0375537	.3289522
size6	.0483387	.068087	0.71	0.478	-.0851093	.1817867
size5	.0419074	.0583517	0.72	0.473	-.0724597	.1562745
size4	-.0949861	.0550881	-1.72	0.085	-.2029568	.0129846
size3	-.077504	.0751606	-1.03	0.302	-.2248161	.0698081
size2	.0957846	.077439	1.24	0.216	-.0559929	.2475622
size	.0519039	.0895246	0.58	0.562	-.1235612	.227369
cocina11	.2217428	.3151761	0.70	0.482	-.3959911	.8394766
cocina10	-.7593694	.3574374	-2.12	0.034	-1.459934	-.058805
cocina9	-.0736318	.3350711	-0.22	0.826	-.7303591	.5830955
cocina8	.1488665	.2965098	0.50	0.616	-.432282	.7300149
cocina7	-.0252326	.3392378	-0.07	0.941	-.6901263	.6396612
cocina6	-.3026136	.3874165	-0.78	0.435	-1.061936	.4567087
cocina5	-.206043	.2760963	-0.75	0.456	-.7471819	.3350959
cocina4	-.0763524	.2749517	-0.28	0.781	-.6152479	.462543
cocina3	.4440063	.2691168	1.65	0.099	-.0834529	.9714656
cocina2	-.3638074	.297304	-1.22	0.221	-.9465126	.2188978
cocina	-.074406	.2778403	-0.27	0.789	-.618963	.470151
hired11	.1277816	.3215622	0.40	0.691	-.5024687	.7580319
hired10	-.0887962	.3680699	-0.24	0.809	-.8102	.6326075
hired9	-.6021184	.3415556	-1.76	0.078	-1.271555	.0673184

hired8	-.0199912	.3070437	-0.07	0.948	-.6217857	.5818033
hired7	.6388382	.3093187	2.07	0.039	.0325846	1.245092
hired6	-.0225695	.3417952	-0.07	0.947	-.6924758	.6473367
hired5	.4221641	.2603805	1.62	0.105	-.0881723	.9325005
hired4	.1599919	.3023165	0.53	0.597	-.4325376	.7525215
hired3	-.0026872	.3194809	-0.01	0.993	-.6288582	.6234838
hired2	-.268161	.2617717	-1.02	0.306	-.781224	.2449021
hired	.2796976	.3222632	0.87	0.385	-.3519266	.9113217
member11	.669638	.2692412	2.49	0.013	.1419349	1.197341
member10	.6896426	.3274487	2.11	0.035	.047855	1.33143
member9	1.205023	.3604729	3.34	0.001	.498509	1.911537
member8	1.434358	.2904618	4.94	0.000	.865063	2.003652
member7	.2943495	.3458881	0.85	0.395	-.3835787	.9722777
member6	-.0184995	.3342877	-0.06	0.956	-.6736914	.6366923
member5	.2759403	.2911728	0.95	0.343	-.2947479	.8466284
member4	.7730406	.271327	2.85	0.004	.2412495	1.304832
member3	.468972	.3654139	1.28	0.199	-.247226	1.18517
member2	-.3286627	.314758	-1.04	0.296	-.945577	.2882516
member	.795597	.2348899	3.39	0.001	.3352214	1.255973
prim11	-.4657898	.351638	-1.32	0.185	-1.154988	.2234081
prim10	-.9677675	.3445695	-2.81	0.005	-1.643111	-.2924236
prim9	.7270253	.4700322	1.55	0.122	-.1942209	1.648272
prim8	-.4521293	.4347786	-1.04	0.298	-1.30428	.4000211
prim7	.347744	.504615	0.69	0.491	-.6412832	1.336771
prim6	-.0537237	.5260292	-0.10	0.919	-1.084722	.9772746
prim5	.6299162	.5516137	1.14	0.253	-.4512268	1.711059
prim4	-1.234841	.5345983	-2.31	0.021	-2.282634	-.1870474
prim3	-1.274303	.4702272	-2.71	0.007	-2.195932	-.352675
prim2	-.1867319	.3834571	-0.49	0.626	-.938294	.5648302
primary	-1.068453	.4688045	-2.28	0.023	-1.987293	-.1496132
lstock	.019639	.0144523	1.36	0.174	-.0086869	.0479649
lstock2	-.0092679	.0164494	-0.56	0.573	-.0415081	.0229723
lstock3	.0130754	.0223091	0.59	0.558	-.0306497	.0568004
lstock4	.0463348	.0198433	2.34	0.020	.0074425	.085227
lstock5	-.0002535	.0181087	-0.01	0.989	-.035746	.0352389
lstock6	.0044062	.0203134	0.22	0.828	-.0354074	.0442198
lstock7	-.0021036	.0208151	-0.10	0.920	-.0429005	.0386933
lstock8	-.0252419	.0209886	-1.20	0.229	-.0663788	.015895
lstock9	-.0044528	.0164859	-0.27	0.787	-.0367645	.0278589
lstock10	.0146672	.0174031	0.84	0.399	-.0194423	.0487768
lstock11	.0225362	.0135016	1.67	0.095	-.0039265	.0489989
fa	1.595095	1.102579	1.45	0.148	-.5659192	3.756109
fc	.8050553	.7563076	1.06	0.287	-.6772804	2.287391
bc	-2.254644	.694911	-3.24	0.001	-3.616645	-.8926438
bd	-2.57119	.9441333	-2.72	0.006	-4.421657	-.7207228
_cons	.2937716	.3864487	0.76	0.447	-.4636539	1.051197
/athrho	-14.20589	.10354	-137.20	0.000	-14.40882	-14.00295
/lnsigma	.1134927	.0470237	2.41	0.016	.0213278	.2056575
rho	-1	1.90e-13			-1	-1

```
     sigma |   1.120184   .0526752                      1.021557    1.228332
    lambda |  -1.120184   .0526752                     -1.223425   -1.016942
------------------------------------------------------------------------------
Wald test of indep. eqns. (rho = 0): chi2(1) = 18824.38   Prob > chi2 = 0.0000
------------------------------------------------------------------------------
```