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Analysis of a Climatically Variable Production Season

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Analysis of a small agropastoral community in Bolivia during a climatically vulnerable year, provided insight into how households diversify and change productions strategies in order to secure income and food consumption. Twelve independent variables that identified distinct production strategies were analyzed according to how well they estimated total income. A subset selection process determined the best combination of variables, or production strategies. The four variables chosen were food plots, shared land, off farm income and number of native animals. These variables characterize traditional farming practices and have social and human capital embedded within them. It is important to understand how households mitigate and cope with climatic risks, in order to best develop methods that can help households during risky production seasons.

INTRODUCTION

Data used in this analysis was extracted from the small peasant community of San José Llanga in the Bolivian Altiplano. San Jose participated in the Small Ruminant Collaborative Research Support Program-Bolivia (SR-CRSP), which was conducted from 1992-1995. SR-CRSP focused on understanding how the introduction of improved varieties of sheep and cattle affects household welfare.

The purpose of using this data in this research differs from the initial analysis. It is the hopes of this research project to identify household strategies and characteristics that aid farmers in securing income and food consumption in a harsh climatic zone. San José Llanga is particularly susceptible to climatic changes, since it is located between 3,725 and 3,786 meters above sea level. Frosts, droughts, and wind erosion are prevalent climatic events that affect production decisions and food security. Data from 1995 will be used since this was a drought year and it is assumed that household will secure income and food consumption, by employing traditional agricultural practices that are less vulnerable to the perturbations of climate.

First an examination of literature that relates to household production systems and climatic vulnerability will be discussed. Second the research problem, setting and design will discussed. In the third part the independent and dependent variables will be analyzed and the correlation matrix examined. In the fourth section initial subset selection procedures will be tested, followed by a discussion of the final model. Then in the technical discussion section possible caveats to the model will be explored. Finally the findings and implications of the research will be examined.

LITERATURE REVIEW

Constrains to choice sets, climate, knowledge systems and social and human capital have influential roles in the ability of a household to secure income and food and the livelihood strategies employed. The political, social and physical environment of rural households' surroundings also influences the stability and decisions of the households. Any changes in these factors can affect the stability and capabilities of the household to secure income and food for present and future consumption. Therefore households construct diverse portfolios of economic activities and secure social support systems in order to stabilize or increase household welfare (Ellis, 1998). The strategies employed by households are not stable and fluctuate depending on the given parameters.

The economic activities of the household portfolio characterize it as both a producer and a consumer. The household must produce to secure income but also to ensure that there is an adequate supply of food throughout the agricultural year. Ellis (1993) describes this as a partial engagement of the household in market activities, which will fluctuate depending on market prices, agricultural productivity, and household needs. The partial engagement of households in the market place is necessary because of the instability of prices and the need of households to mitigate risk. Households will decide the mix of market and non-market activities that is needed to mitigate risk, acquire capital, and secure income and food consumption.

The diversification of the household's economic activities will depend on the household's access to resources, available labor supply and goals. These constraints define the options available to households, or the available choice sets (North, 1990). The ability of the household to access land, capital, or other inputs affects their choices in what economic activities to invest in. If a household is constrained by land then an increase in the number of livestock or crops produced will not be a viable option. Also if labor is the limiting factor then households will invest in labor saving activities. The goals or objectives of the household also influence income diversification. A household concerned with risk management will invest in activities that secure income and food, as opposed to households that aim to secure goods and services for future use (Ellis, 1998 and Reardon, 1988). While these factors constrain the choice sets of households and influence the production strategies and the ability of households to increase their standard of living, households can access resources by utilizing their human and social capital.

The embedded nature of social and human capital often explain why some households may use different strategies or have access to diverse resources (de Haan, forthcoming). Social capital is a public good (Putnam, 1993) and is a by-product of social activities and networks (Coleman, 1998). It helps to create social structure and facilitate certain actions within a social structure (Coleman, 1998). Households with a high amount of social capital increase economic activities and opportunities, since they will have more linkages to credit and social networks (Light, 1972). Although the direct effect of social capital is debated, it can play an important role in a peasant household whose production strategies are constrained by lack of resources or credit. Social capital increases a household's ability to access resources through social networks and the institutional structure of the region. Human capital is also an important factor and is defined as the amount of labor and education within a family. Human capital affects the decisions of households and also affects their ability to access resources. The number of people in a household will increase the ability to diversify and high educational levels may increase the ability of households to access information and resources.

The mix of risk mitigation and capital accumulation strategies is impacted by a household's ability to cope and survive in an agricultural vulnerable year. Climate variability increases the amount of risk that households will encounter during the agricultural year. Crop and livestock productivity are affected by climate variability, such as frosts, droughts and interannual variations. If households must manage agricultural production in climatic variable regions then their available coping strategies will impact their diversification strategies. The risk of weather variation may be a reason for low covariation in agriculture, especially when farmers have limited coping strategies (Rosenzweig and Binswanger, 1993). The limitations of households increase the need to invest in risk management techniques, such as diversification and spatial variability of food plots or the use of native breeds of livestock (Walker and Jodha, 1986). While some climatic variation is a common occurrence, there are climatic anomalies, which drastically affect the security of households. One of these events is the El Niño Southern Oscillation (ENSO) event, which warms and cools the water of the equatorial Pacific Ocean (Stern and Easterling, 1999). ENSO events have a dramatic impact on Andean countries of South America, such as floods in Peru and Ecuador and drought in Bolivia and NE Brazil (Finan, 1999 and Broad, 1999). These events make the incorporation of risk-management and diversification strategies a necessity for peasant households. Households must incorporate adaptive strategies for the climatic stresses but also coping strategies that help households during periods of climatic shocks. The larger amount of risk associated with climate variability will increase diversification methods and strategies and dynamic nature of households (Rosenzweig and Binswanger, 1993).

In order to cope with climatic variability, farmers use a series of indicators to plan production activities. Indicators, such as animals, constellation, plants and abiotic factors aid farmers planning risk management strategies (Bharara, 1994 and Osunade, 1994, Hatch, 1983). Indicators were developed by observations, experiences and information passed down by previous generations constitute a local knowledge base (Hatch, 1983 and Céspedes and Rodriguez, unpublished). Although the successes of these indicators are not supported by statistical analysis (Osunade, 1994), they provide farmers with a set of rules and strategies to employ when specific events are observed (Bharara, 1994). These sets of rules, or local knowledge systems, will not be completely replaced by scientific forecasting methods (Bharara, 1994 and Osunade, 1994), instead they have melded with modern technology. Farmers have incorporated modern practices into their local practices (Markowitz and Valdivia, forthcoming), by a process of revising local knowledge systems, reinterpreting prior ideas and incorporating the new systems (Bebbington, 1991). Household may also utilize social and human capital to increase diversification or augment coping strategies during climatically vulnerable years. Revisions and modifications demonstrate the dynamic nature of production strategies and the ability of farmers to adjust to given circumstances (Bebbington, 1991).

RESEARCH PROBLEM

During periods of stress households must increase their adaptive and coping strategies in order to secure income and food consumption. Therefore it is important to understand how diversification strategies change and adapt to climatically vulnerable years. It is the objective of this research to identify the main strategies that households employ to secure income and food consumption during a climatically vulnerable year. It is hypothesized that households will choose strategies that mitigate risk and will utilize their human and social capital to access more resources. It is the hopes that this research project will identify household strategies and characteristics that aid farmers in securing income and food consumption in a harsh climatic zone.

RESEARCH SETTTING:

The Bolivian highlands was chosen for this research project because it is particularly vulnerable to climate variability, which affects the production practices and economic activities of the Aymara and Quechua communities that farm and reside in the harsh Andean climate. Droughts, frosts and wind erosion are common occurrences but during El Niño events droughts are more prevalent. Erratic rains and low rainfall affect crop and livestock production. Over 285,000 residents live in the highlands, which is located at 3650-4800 meters above sea level (Francois, 1999). Food insecurity is a daily concern and small farmers produce for home consumption and local markets (Jovel. 1989 and Francois). Households in this region are constrained by the political and social environment, which lead to the instability of market prices and the economy as a whole (Library of Congress, 2000). Therefore peasant farmers can be described, as both producers and consumers and the livelihood strategy approach will help in the analysis of their economic activities.

Research was conducted in the community of San José Llanga, located in the Bolivian Altiplano 116km south of La Paz, at an altitude between 3,725 and 3,786 meters above sea level (Valdivia and Jetté). The community is approximately 7,200 hectares, which are divided into six distinct zones or neighborhoods: Espiritu Willquí, Incamaya, Thola Tia, Barrio, Savilani, and Callunimaya (Alvarez, 1994). There were approximately 430 people living in the community in 118 households (Cespedes-Estevez, 1993). Due to its high altitude San José Llanga is susceptible to extremes in temperatures, frosts, droughts and other climatic variations characteristic of mountain regions (Alvarez, 1994). Although San José has more than thirty years of experience with the introduction of improved technology and information, there has been little specialization of household production systems (Markowitz and Valdivia, forthcoming).

RESEARCH DESIGN:

The Small Ruminant Collaborative Research Project collected data from San Jose Llanga in 1993 and 1995. Data from 1995 will be used since this was a drought year and it is assumed that household will secure income and food consumption, by employing traditional agricultural practices that are less vulnerable to the perturbations of climate. In this year households will also utilize social and human capital to access more resources. In order to conduct this research variables from the data collected will be identified that characterize diverse production strategies and indicate the use of social and human capital. The variables that best estimate total income will be identified through a subset selection process

IDENTIFICATION OF DEPENDENT AND INDEPENDENT VARIABLES

The dependent variable is total income earned by the family in dollars. The components of income were the production of crops and livestock, off farm income, transfers or other income sources. Total income captures the importance of food security and purchasing power of households. Summing cash received from market sales and the opportunity cost of consuming the remaining production at home equals the total income earned from crops and livestock. The amount was calculated in Bolivians and then converted into U.S. dollars using the official exchange rate for the year. Preliminary scatter plots of the twelve independent variables against income were skewed. Therefore the log of the income was calculated and used as the dependent variable.

The first set of variables relates to the demographics of the household. The first variable is the number of family members that lived in the household. Although the number of family members is important, each member is unable to contribute the same amount of labor per person. To estimate the labor strength of the household an equivalency unit was calculated which weights each household member according to their age. The education levels of the household also impacts strategies, and were calculated by adding the number of years of education of every household member over the age of 18.

The second set of variables relates to crop production methods. The number of food plots per household was calculated, since as the plot numbers increase food security is greater and climatic vulnerability decreases. Sharing land is another important strategy as it increases the amount of land a family has access to. Both of these strategies have social capital embedded within them, since they relate to a household's ability to access social networks and institutions.

The third set of variables relates to livestock production. Native breeds are more resilient than improved breeds, although they do not generate as much income. The number of native and improved animals was calculated. Native animals relates to a risk mitigation strategy, while improved varieties indicate a strategy to increase market involvement. Sheep that are shared between families increases security for households. If a household is taking care of animals that do not belong to the family it can be identified as an investment function, since a family receives any offspring of the animals. Both the number of grazed sheep and grazed cows was calculated and also indicate the ability of a household to access social capital.

The fourth strategy to increase the household economic portfolio is by accessing off farm income sources. Households that have off farm work have made the decision to channel household resources into non-agricultural areas. This variable is categorical, with yes equal to one and no equal to zero. Households also increase security by receiving money from family or friends that live in other regions of the country, or remittances. These variables have social and human capital embedded within them.

CORRELATION MATRIX:

A correlation matrix was calculated for the independent and dependent variables. The correlation matrix shows the relationship between variables, by indicating the correlation coefficient. The correlation coefficient measures the degree of the relation from –1.0 to 1.0 (Vogt, 1999). The correlation matrix reveled that the labor index was highly correlated with the education index and the number of family members. Education index was correlated with labor index at .76364 and with family size at .78257. Both were statistically significant at the .01 level (See Table 1). Conceptually the use of the labor index provides a better analysis of resources that are available for a household to employ, since labor strength is an influential factor in production decisions.

TABLE 1: Pearson Correlation Coefficients of Variables

	Labor Index	Education Index	Family Size	Shared Sheep
Labor Index	1.00	.7634*	.9351*	.519
Education Index	.7634*	1.00	.7825*	.2985
Family Size	.935*	.7825*	1.00	.3908

*Statistically significant at the .01 level
Data from SR-CRSP 1995 surveys.

A few variables were negatively correlated, such as the labor index and remittances. Also off farm income was negatively correlated with the livestock and crop production variables. This makes theoretical sense since if you decide to work off the farm you decrease activity in the farm sector. Other negative correlations were observed but the most interesting was with native animals, which was negatively correlated with improved animals, shared land and grazed cows. This suggests that households with native animals will not invest in as many improved breeds or cattle, and may not have the resources to access other forms of production strategies, such as crop production.

ANALYSIS OF INDEPENDNET VARIABLES IN EXPLAINING TOTAL INCOME

Upon first analysis of the indicated variables an outlier was identified as a household that had an income greater than $8,000. After the outlier was deleted from the sample and analysis of which twelve independent variables were significant in explaining income during the climatically vulnerable year could be conducted. In order to determine which strategies were important for 1995 a subset selection process will be used. Forward, backward and forward stepwise selection procedures will help identify the subset of variables that best explain the dependent variable. Forward selection chooses which variables should be included and in which order. Backward selection eliminates independent variables from the model if they do not meet the selected significance level. Forward stepwise selection combines both backward and forward selection procedures (Vogt, 1999). These three methods will be used to compare and contrast the subsets identified. To validate the subset a different selection procedure will be used. Analysis of R-squared and C(p) values will also help in determining the best subset of variables. The variables chosen to analyze summarize the production strategies used to ensure income and food security. The subset selection procedure will aid in determining which variables, production strategies, were important for the climatically vulnerable year.

Before beginning the subset selection procedures independent variables that are significantly correlated need to be examined. The labor index was chosen as a good proxy of household characteristics and human capital. Therefore family size and education level will not be used. Shared sheep was highly correlated with the labor index and was dropped from the model to decrease problems of multicollinearity. Therefore nine variables will be analyzed to determine which subset best explains total income.

SUBSET SELECTION PROCESS:

Forward, backward and forward stepwise selection procedures were used to select a subset of variables that would be the best predictor of the dependent variable. The forward selection procedure identified food plots, native animals, shared land and off farm income as the best subset of variables (See Table 2). All other variables were not added to the model because they did not meet the .10 significance level for entry into the model. The R-squared for the model is .64 with an F value of 10.66. This same subset of variables was also identified with Backward and Forward Stepwise procedure.

Table 2: Summary of Forward Selection Model

Variable	Parameter Estimate	P-Value	Standard Error
Intercept	4.914	.000	112.499
Food Plots	.0324	.000	17.44
Off farm Income	.6347	.057	.3168
Native Animals	.0275	.004	.0086
Shared Land	.0738	.0496	.0356

Theoretically labor strength is an essential component of household welfare. Therefore to test the impact the labor unit on the model, this variable was forced into

Forward Stepwise selection (See Table 3) to analyze the effect of its addition on the other variables. The results showed that with the addition of labor unit the selection process entered only food plots and the parameter estimate was also changed. The R-squared for this model was .524 with an F-vale of 13.79. This adds an interesting dimension to the analysis, since the labor unit may be embedded within the other production strategies.

TABLE 3: Summary of Forward Stepwise Selection with Labor Unit

Variable	Parameter Estimate	P-Value	Standard Error
Intercept	5.397	.000	.3216
Labor Unit	.2343	.0227	.0952
Food Plots	.0242	.0019	.007

To test subset of variables chosen in the first selection process is the adjusted R-squared and C(p) value was analyzed according to analyze different models. The C(p) value examines the size of the sum of the squared errors and bias in the models. A small value suggests a small sum of squared errors. If the C(p) value is also close to the number of parameters then the model will have little bias, however this does not always hold. This analysis showed that the subset of variables indicated by the former selection processes has the lowest C(p) at 1.4762 and the second highest adjusted R-squared at .588652. The subset of variables with the highest adjusted R-squared, .590583, also had the second highest C(p) at 2.5334 (See Table 4). This subset included food plots, off farm income, grazed cows, native animals, and shared land. Neither of the C(p) values were close to the number of parameters in the model.

TABLE 4: R-squared and C(p) Analysis

Subset of Variables	C(p)	R-Squared
A) Food Plots Shared Land Native Animals Off farm income	1.4762	.588652
B) Food Plots Off farm income Grazed Cows Native Animals Shared Land	2.5334	.590583

Since Subset B included an additional variable, grazed cows, regressions were run on both of these models to analyze the differences between the two. The regression of Subset B is summarized in Table 5. The p-value for this model was .0001 with an F value of 8.789, indicating that at least one of the parameters is not equal to zero with an adjusted R-squared of .5906. All the variables have a p-value less then .05 except grazed cows, at .3038.

TABLE 5: Summary of Subset B Regression Analysis

Variable	Parameter Estimate	Standard Error	P-Vlaue
Intercept	4.768	.389	.0000
Food Plots	.0328	.0061	.0000
Native Animals	.0273	.0085	.004
Grazed Cows	.0927	.088	.3038
Off farm Income	.7033	.322	.0403
Shared Land	.0758	.0355	.0446

The second regression was done on Subset A (Table 6). The F-value for this model was 10.66 with a p-value of .0001, indicating that at least one of the parameters is not equal to zero. Only off farm income had a p-value greater than .05 at .0570. The adjusted R-squared of the model is .5887.

Table 6: Summary of Subset A Regression Analysis

Variable	Parameter Estimate	P-Value	Standard Error
Intercept	4.914	.000	112.499
Food Plots	.0324	.000	17.44
Off farm Income	.6347	.057	.3168
Native Animals	.0275	.004	.0086
Shared Land	.0738	.0496	.0356

To determine if there are differences between these models and to examine if grazed cows should be kept in the final model an F-test was conducted. The calculated F value was 1.108, which is less then the calculated F value, 4.26, at confidence level .05 with 1 numerator degree of freedom and 22 denominator degrees of freedom. Therefore the null hypothesis, that the reduced model is sufficient, cannot be rejected and the final model will include only four variables, food plots, off farm income, shared land and native animals.

ANALYSIS OF THE FINAL MODEL

The final model includes the variables food plots, native animals, off farm income and shared land. An analysis of the residuals was done to determine if there were any outliers in the observations. RSTUDENT, Cook's Distance, DFFITS and DFBETAS for all the observations were computed. Observation number 5 had a RSTUDENT, -4.1153, larger than the rejection value of 3.792. Although Cook's Distance and DFFITS were not close to the rejection value, the DFBETAS were higher than all the other observations. It was decided to drop this observation from the sample to examine any changes in the parameters. No other observations were noted to have outlier properties.

A final regression was done using the indicated subset of variables with a sample size of twenty-seven (See Table 7). The F-value of this model is 13.539 with a p-value of .0001, indicating that at least one of the parameters does not equal zero. The adjusted R-squared is larger than the previous regression, at .6586. All the variables are significant at the .05 level. Also all the parameter estimates changed with the deletion of the outlier, especially food plots, off farm income and shared land.

TABLE 7: SUMMARY OF FINAL MODEL:

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	P-VALUE
INTEREPT	5.133548	0.28512452	0.0001
FOOD PLOTS (FP)	0.028945	0.00477027	0.0001
SHARED LAND (SL)	0.063272	0.02750721	0.0313
NATIVE ANIMALS (NA)	0.023238	0.00667243	0.0021
OFF FARM INCOME (OFF)	0.726794	0.24455086	0.0070

The plot of the residuals against the predicted total income shows no major changes in variance There also appears to be no major departure from normalcy on the normal probability plot and the plot of residual against nscore. The nscore, .9804, is also greater than the coefficient of correlation, .962 at confidence level .05 and sample size 28, indicating that the errors are normally distributed.

Therefore total income can be expressed as follows (t-values in parentheses):

$$Y = \underset{(18.05)}{5.133} + \underset{(6.068)}{.0289\,FP} + \underset{(2.300)}{.0632SL} + \underset{(3.483)}{.0232NA} + \underset{(2.972)}{.7267\,OFF}$$

TECHNICAL DISUCSSION

The method of analyzing subset of variables is important to understand what production strategies are utilized during a climatically vulnerable year. However there are a few caveats to this analysis. First demographics were not included in the final model. It was concluded that household characteristics, or human capital, are embedded in the other variables, but possibly a better proxy could be used. For example the education level index was highly correlated with the other household variables but was not correlated with other independent variables. Therefore if the education level variable was used in the model different results may have been observed.

Also when the final subset of explanatory variables was chosen two outliers were identified. If these observations were dropped earlier in the analysis a different subset might have been observed during the subset selection process. Also if Subset B was analyzed with these outliers there might have been different theoretical interpretations.

An examination of these caveats needs to be conducted in order to have a more robust model.

FINDINGS AND IMPLICATIONS

The purpose of the project was to identify production strategies and household characteristics that aid income and food consumption security in a climatic vulnerable zone. It is important to identify what strategies are important during high-risk production seasons to understand what mechanisms households employ to cope and mitigate risks. Also the production strategies may be distinct to normal production seasons. The production strategies identified are the number of food plots planted, the amount of hectares shared with other families, the number of native animals in the household, and off farm income source. These variables were identified using subset selection procedures. Therefore eight variables were excluded from the final model. It is interesting that household characteristics were excluded from the model, since education and labor strength have been proven to be important components of household welfare. Therefore this model indicates that household characteristics are embedded in the production strategies of households. For example households with a large amount of labor can farm more plots and have more animals. Also family members with a higher education level will have more opportunities to secure off farm employment. Therefore to analyze the effect of household characteristics on income a recursive regression might be more appropriate since human capital is embedded in the model. Or a better indicator of human capital needs to be identified.

The variables that were included in the final model provide an important analysis of production strategies that households employ during climatic vulnerable years. All four variables were traditional farming practices. The use of native animals is a traditional farming method, which decreases household risk and vulnerability. Native animals are adapted to the harsh environment of San José Llanga and provide more security to households than improved breeds. The use of many food plots increases spatial variability, which protects farmers against dramatic climatic events. The strategy of sharing land with other families is another traditional farming method that allows for farmers to increase the number of crops planted without renting or buying new land. The last variable, off farm income, indicates the ability of households to find off farm employment to buffer the effect of a climatically harsh year. This analysis supports the view that farmers at the subsistence level rely on traditional agricultural methods to secure income and food consumption during vulnerable years. Also it indicates the use of social capital by households to secure income and food consumption. This has important implications for aid and development projects, which at times attempt to introduce cash crops and improved animal breeds into rural areas of developing countries. Development projects should attempt to increase the security of subsistence farmers, by addressing the production strategies that farmers and households have employed for generations.

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