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RESEARCH ARTICLE

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Explaining food insecurity among indigenous households of the Sierra Tarahumara in the Mexican state of Chihuahua

Otilia-Vanessa Cordero-Ahiman[1], Eduardo Santellano-Estrada[2] and Alberto Garrido[1]

[1]Universidad Politécnica de Madrid, Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM). Dept. Economía Agraria, Estadística y Gestión de Empresas. C/ Senda del Rey 13, 28040 Madrid, Spain [2]Universidad Autónoma de Chihuahua, Centro de Extensión e Innovación Rural Noroeste (CEIR). Perif. Francisco R. Almada Km. 1, 31453 Chihuahua, Mexico

Abstract

Numerous studies have analyzed the factors that determine food security and explored the problem from regional or national points of view. However, there has been less research targeting an understanding of the food security problem at the household level in specific rural locations like indigenous communities. Indigenous groups are recognized as priority groups in Mexico, because they live in a situation of poverty. For this reason, the objective of this research was to investigate the determinants of food insecurity among the indigenous communities of the Sierra Tarahumara in Mexico. We used the Latin American and Caribbean Household Food Security Measurement Scale (ELCSA). This scale is useful for measuring food insecurity levels in households. A questionnaire was administered to 123 households. We employed the method based on Cronbach's alpha to measure internal consistency, which was 0.96. In addition, we estimated the main determinants of household food insecurity using both ordered logit model and binomial logit model. We found that approximately 59.35% of households were living in a situation of severe food insecurity. The two predictive models applied suggest that: i) income is the most important determinant of access to food; ii) increased maize production improves food security; iii) farmers consume their seed stocks in times of food scarcity, and iv) households are food insecure when the householders are in casual employment. Akaike's information criterion and the Bayesian information criterion suggest that the goodness of fit to the data was better for the ordered logit model.

Additional key words: ELCSA; measurement; poverty; human health; logit model.

Abbreviations used: AIC (Akaike's information criterion); BIC (Bayesian information criterion); BLM (Binomial logit model); CCHIP (Community Childhood Hunger Identification Project); ELCSA (Latin American and Caribbean Household Food Security Measurement Scale); FI (Food insecurity); HDI (Human Development Index); HFSSM (Household Food Security Survey Module); OLM (Ordered logit model)

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Correspondence should be addressed to Otilia-Vanessa Cordero-Ahiman: ov.cordero.ahiman@gmail.com

Introduction

About 795 million people are undernourished globally. Therefore, the eradication of hunger and poverty is still a challenge to be addressed with even greater intensity and focus (FAO/IFAD/WFP, 2015; UN, 2016).

The measurement of food security status in households has been the subject of numerous investigations. The first measurement scales began in the USA, as laid down in the report to National Nutrition Monitoring and Related Research Act. This report tried to standardize measurement tools to get and set data on the prevalence of food insecurity (FI) (Hamilton, 1997; Melgar & Hackett, 2008; FAO, 2012). As a result of this research, two instruments of measurement were defined: the Community Childhood Hunger Identification Project (CCHIP) (Wehler *et al*., 1992; Carlson *et al*.,

1999, FAO, 2012) and Radimer/Cornell hunger scale (Radimer *et al*., 1992; Carlson *et al*., 1999; FAO, 2012). In the mid-1990s, these two instruments were replaced by the Household Food Security Supplemental Module (HFSSM). The HFSSM provided a clear assessment of the food security situation of the USA. This instrument has been adjusted and validated since then. This adjusted and validated HFSSM has been included in several population and health surveys in a number of countries around the world (Carlson *et al*., 1999; Nord *et al*., 2007; Melgar & Hackett, 2008; Nord & Parker, 2010; FAO, 2012; Pérez-Escamilla, 2012).

In Latin America and the Caribbean, variants of these scales measuring FI were adapted and applied in the Community Childhood Hunger Identification Project (CCHIP) in Venezuela (Lorenzana & Sanjur, 1999). The HFSSM was later adapted in Colombia (Hackett *et al*., 2008), Brazil (Brazilian Food Security Scale, EBIA) (Segall-Corrêa *et al*., 2014), Bolivia (Melgar *et al*., 2006; Pérez-Escamilla, 2012), Ecuador (Hackett *et al.,* 2007) and Trinidad and Tobago (Gulliford *et al*., 2006). These previous experiences of scales measuring food security at household level were consolidated in the Latin American and Caribbean Household Food Security Measurement Scale (ELCSA). This scale can be used to assess the FI level in households and detect changes in the quality and quantity of food consumed, taking into account the resources available to each household in the past three months (FAO, 2012). Several studies were conducted to validate this new instrument in a number of countries in this region, including Guatemala (Melgar *et al*., 2010), Haiti (Pérez-Escamilla *et al.,* 2009), Mexico (Melgar *et al*., 2005, 2010; Shamah-Levy *et al*., 2014; Villagómez-Ornelas *et al*., 2014), Dominican Republic (Bezuneh *et al*., 2007) and other countries.

Mexico has not been impervious to the economic and financial price crisis. This has resulted in an increase in the number of households and people having insecure access to food (FAO, 2013). The 2011 reform of the Mexican Constitution to consider the right to food was a major advance. But the FI situation still paints a complex picture. Poverty levels tend to be higher in states that have been identified as priority areas, where the population is rural (<2500 inhabitants), indigenous (more than 40% of Mexican population is indigenous) and settled at a distance from metropolitan areas. Such states also tend to have the highest deficiency levels with respect to food access (FAO, 2013, 2015; CONEVAL, 2016a).The indigenous population is among the poorest and most disadvantaged strata of society, where living standards are below national and regional averages and the minimum welfare levels defined by various international organizations (Suárez, 2005; CDI/PNUD, 2006a).

In Mexico there are food aid programs that aim to contribute to improving the nutritional status of the most vulnerable populations: 1) Prospera is the main social inclusion program providing bimonthly conditional cash transfers; 2) the Food Support Program (PAL) provides bimonthly cash or card transfers for the purchase of a set of predefined products in stores supplied by DICONSA; 3) the Rural Supply Program run by DICONSA (PAR) provides a basic food basket at reduced rates (<15%); 4) the Social Milk Supply Program run by Liconsa (PASL) targets the population with income below the poverty line and provides for weekly milk delivery through the sale of liquid and powdered milk for community supply or under agreement with social players (CONEVAL, 2016b).

Delving into the socioeconomic problems and the FI situation affecting most of the rural population, especially indigenous communities, is essential for the design and evaluation of public policies in the Mexican scenario. It is vital in this context to have accessible, accurate and up-to-date information on the problems of rural households that could be addressed by public policies. While there are several sources of information that provide insight into specific aspects of rural households in Mexico, none is sufficient to paint a complete picture of this sector of the population. The fact that they share the same general shortcomings does not mean that all indigenous peoples are alike (Fernandez *et al.,* 2006; CONEVAL, 2015).

In Mexico, the severe drought that occurred in 2012 left two million people without access to water and, in addition to, devastated cropland in nearly half of the country. This lack of and accessibility to food had a significant negative impact on the nutrition and health status fundamentally of poor Mexican population. Among the more seriously affected were the indigenous communities of the Sierra Tarahumara, which are known to stand among the Mexico's poorest citizens (Zabludovsky, 2012).

There has been no recent update of information on the FI situation of indigenous communities in Mexico and in particular the Sierra Tarahumara. This constitutes an important limitation for monitoring the Global Sustainable Development Goals (Goal 2: Zero Hunger) (UN, 2016), signed by the Mexican government. Indigenous communities of the Sierra Tarahumara are very isolated and very few are accessible by road, infrastructure is very expensive. This is an obstacle to the provision of services like education, healthcare, water and electricity. These long-term disadvantages have driven this region into poverty and FI (Saucedo *et al*., 2012). According to development indicators in Mexico, the Sierra Tarahumara ranks 20th (Human Development Index HDI=0.64) with lower

development and greater inequality of indigenous (HDI of 0.54) with respect to non-indigenous (HDI of 0.78) people, that is, a 30.3% difference between the two populations (CDI/PNUD, 2006b). On this ground, the Mexican Ministry of Agriculture (Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food, SAGARPA) supported this research that should help to provide local and national political decision makers with updated information in order to identify inconsistencies in policies and programs related to food security. Our research is up-to-date and helps to identify the determinants of FI in households of the Sierra Tarahumara, located in the southwestern part of the state of Chihuahua.

Material and methods

Study area

The Sierra Tarahumara is a mountain range located in the Sierra Madre in the state of Chihuahua in northwestern Mexico. It consists of a series of deep canyons alternating subtropical high mountains up to 3300 m asl. It is characterized by a great diversity of flora and tropical, subtropical and temperate wildlife, including a number of unique species in the world (LaRochelle & Berkes, 2003). The Sierra Tarahumara is considered a forest region and has 4.5 million hectares of pine-oak forests. The area accounts for about 15% of forest cover in Mexico and 10% of national forest area under management. User groups —ejidos and agricultural communities (Pérez-Cirera & Lovett, 2006)— manage 84% of forests under a common property regime. The Sierra Tarahumara is also an area of cultural diversity, since there are four indigenous ethnic groups: Rarámuri or Tarahumara, Pima, Guarojío and Tepehuanes. Most of the indigenous population of the Sierra is Rarámuri, one of the largest groups of indigenous peoples in Mexico (LaRochelle & Berkes, 2003; Saucedo *et al*., 2003).

Data collection

The communities of the Sierra Tarahumara in Chihuahua were selected using a simple random sampling method. They were classified according to the distance to the nearest centre of development, which, in this case, was the town of Creel (0-3 km, 3-6 km, 6-9 km and 9-12 km). Creel is considered to be the gateway to the Sierra Tarahumara and has a developed tourist sector (Farias & Aranda, 2008). The communities were selected from a list of communities provided by the Mexican National Institute of Statistics and Geography (INEGI). The representative sample was made up 125 households in 38 communities, with a confidence level of 95% and a precision of 7%. The survey was conducted face to face and lasted approximately two hours. All respondents were Rarámuris, and interviewers were assisted by interpreters to translate to and from their language. The survey was conducted between February and March 2015 and was spread across different days of the week and different times of the day in order to ensure that all households had an equal chance of being surveyed. Pilot testing of the survey was conducted prior to the definite survey. Apart from expert opinion, the results from the pilot test were used to refine the questions contained in the survey. The sample was rather small because the Rarámuri are the most disperse of all the indigenous groups of Mexico: almost 70% live in communities of 1 to 99 people (CDI/PNUD, 2006a).

Questionnaire

The survey consisted of two questionnaires: a) ELCSA was used to assess the FI level of the household and detect changes in the quality and quantity of food consumed according to the resources to which each household had access during the three months prior to the interview date (FAO, 2012); and b) the agro-socioeconomic questionnaire provided information about the head of household and household characteristics, and land tenure and production.

ELCSA analysis

ELCSA contained 15 questions that were divided into two sections. Section 1 was related to a number of situations that lead to the FI experienced by households and adult household members (questions P1 to P8). Section 2 was related to the conditions affecting children aged under 18 in households (questions P9 to P15) (FAO, 2012). Each question had two possible answers: yes (1) or no (0) (Table 1). From the aggregate score of positive responses, we could estimate the degree of FI of households divided into four levels according to the cutoff points used by ELCSA: 1) no FI, with 0 positive responses; 2) mild FI, between 1and 5 affirmative responses; 3) moderate FI, between 6 and 10 positive responses; and 4) severe FI, with 11 or more affirmative responses (FAO, 2012).

Two households were excluded from the sample because respondents did not complete the 15 necessary questions to define the ELCSA. Therefore, the final sample consisted of 123 households. In each selected household, we surveyed the head of household and/or the woman in charge of preparing food for the family.

Table 1. Food insecurity questionnaire items. English back-translation from Spanish

Items	In the past 3 months, because of a lack of income or other resources,
Q1	Did you ever worry about your household running out of food?
Q2	Did your household ever run out of food?
Q3	Was your household deprived of eating a healthy diet?
Q4	Did you or any other adults in your household ever have an unbalanced diet?
Q5	Did you or any other adults in your household miss breakfast, lunch or dinner?
Q6	Did you or any other adults in your household eat less than you should?
Q7	Were you or any other adults in your household ever hungry and had nothing to eat?
Q8	Did you or any other adults in your household not eat for a whole day or eat only once a day?
Q9	Were any household members deprived of a healthy diet?
Q10	Did any household members under 18 have an unbalanced diet?
Q11	Did any household members under 18 ever miss breakfast, lunch or dinner?
Q12	Did any household members under 18 not have enough to eat?
Q13	Did you ever have to cut the size of the meals prepared for any household members under 18?
Q14	Were any household members under 18 ever hungry and had nothing to eat?
Q15	Did any household members under 18 ever not eat for a whole day or eat only once a day?

Source: FAO (2012)

Evaluation of ELCSA reliability using Cronbach's alpha

Cronbach's alpha coefficient measures the reliability of questionnaire responses and falls within the interval (0, 1). If α is near 0, then the quantified answers are not at all reliable; and if it is close to 1, the responses are very reliable. As a rule of thumb, if $\alpha \geq 0.8$ then the answers are considered reliable (Cronbach, 1951; Leontitsis & Pagge, 2007; FAO, 2012). Therefore, this coefficient was used to assess the reliability of the ELCSA.

X is an n × k matrix of the quantified questionnaire responses. Each row of X represents a subject and each column a question. In this case, the quantified responses are on the scale of 0 to 1. Cronbach's alpha is expressed as:

$$\alpha = \frac{k}{k-1}\left[\frac{\sigma_t^2 - \sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right] \qquad [1]$$

where σ_i^2 is the variance of each column of X, σ_i^2 the variance of the sum of each row of X. In Eq. [1], k is a correction parameter. If the quantified responses are consistent, then σ_i^2 will be relatively large. This will lead α to tend to 1. Otherwise, random responses will lead σ_i^2 to be comparable with the sum of individual variances (σ_i^2). This will in turn lead α to tend to 0 (Leontitsis & Pagge, 2007).

Empirical models

The first step was to identify the dependent and the independent variables that are likely to provide information to explain FI. The models tested all the independent variables in Table 2. However, the variables that best explain the models in this study were: income, consumed seed stocks, tons of maize produced, casual employment, age, household size and Prospera. The second step was to estimate the statistical models.

Ordered logit model (OLM)

There are several types of logistic models. However, when, as is the case of our FI variable, the outcome represents an underlying continuous scale subdivided into many categories, the best modeling framework is an ordered logit model (Greene, 2003; Long & Freese, 2006; Ingelmo *et al*., 2011). The OLM is widely used for analyzing such categorical dependent variables (Greene, 2003; Train, 2009). The OLM can be derived based on the level of an unobserved variable. One fundamental assumption of this model is that the data should meet the proportional odds assumption. The relationship between two levels in the dependent variable group is the same, and therefore the slope coefficients do not vary across different alternatives, except at the cutoff points (Train, 2009; Sasidharana & Menéndez, 2014).

Food insecurity is divided into four categories in increasing order of insecurity and coded as: 0 = no FI, 1 = mild FI, 2 = moderate FI and 3 = severe FI. Note that level J = 0 is defined as the minimum value of the variable (no FI). Let Y_i denote the observed FI level in household i, Y^* the latent FI measure, X the matrix of independent variables. In this study, J = 4. The latent regression of food insecurity Y_i^* is expressed as:

Table 2. Descriptive analysis of the household (n=123)

Variables			
Quantitative	**Description**	**Mean**	**SD**
Income	Income of head of household in Mexican pesos	2199.92	1634.87
Maize production	Tons of maize produced per household	4.94	13.24
Household size	Number of people living together in one house	4.28	1.71
Age	Age of head of household	40.66	13.90
Qualitative	**Description**		**Percentage (%)**
Gender:	Gender of head of household		
Female			34.96
Male			65.04
Marital status:	Marital status of head of household		
Non-marital cohabitation			57.72
Married			14.63
Widower			13.82
Separated			13.82
Education:	Educational level of head of household		
Uneducated			23.58
Primary			61.79
Secondary			10.57
Higher			4.07
Access to water facilities:	Water source used by households		
No facilities			29.27
Waterwheel or well			70.73
Toilet:	Sanitation services		
No access			69.11
Access			30.89
Electricity:	Electricity services		
No access			82.11
Access			17.89
Energy for cooking:	Source of energy for cooking		
Firewood			92.68
Gas			7.32
Land ownership:	Amount of available land owned by head of household		
None			21.95
< 1 ha			9.76
1-2 ha			54.47
>2 ha			13.82
Casual employment:	Householders with temporary employment		
No			65.85
Yes			34.15
Consumed seed stocks:	Households consumed seed reserves for next planting season		
No			58.50
Yes			41.50

Table 2. Continued

Qualitative	Description	Percentage (%)
Situation of poverty	When a person has at least one social deprivation and income is insufficient to purchase the goods and services required to meet their food and non-food needs	26.00
Situation of extreme poverty	When a person has three or more social deprivations and is also below the minimum poverty line. Income is not sufficient for food purchases, *i.e.*, the person is living on less than 1.25 US$/day	18.70
Poverty line (vulnerable due to social deprivation)	Denotes the population that does not have sufficient resources to purchase the goods and services required to meet their basic (food and non-food) needs	24.39
Prospera:	Families that are or are not beneficiaries of this social inclusion and conditional cash transfer program (CCT)	
Non-beneficiary		33.33
Beneficiary		66.67
Dependent	**Description**	**Percentage (%)**
FI:	FI condition (OLM)	
None	0	13.82
Mild	1	10.57
Moderate	2	16.26
Severe	3	59.35
FI:	FI condition (BLM)	
Food security	0 (0 = no FI and mild FI)	24.39
Food insecurity	1 (1 = moderate FI and severe FI)	75.61

Source: Own elaboration from surveys. BLM, binomial logit model. CCT, conditional cash transfer program. FI, food insecurity. OLM, ordered logit model.

$$Y_i^* = X\beta + \varepsilon_i, \quad [2]$$

where i is the observation, β are the regression coefficients for X, is the identically and independently distributed error term.

Let μ_k be the FI thresholds = 1,2,…J - 1. Level k = 1 represents the minimum threshold (no FI). The values of Y are represented as:

Y = 0 no FI if $Y^* \leq \mu_1$
Y = 1 mild FI if $\mu_1 \leq Y^* \leq \mu_2$
Y = 2 moderate FI if $\mu_2 \leq Y^* \leq \mu_3$
Y = 3 severe FI if $Y^* > \mu_3$

Since J is the number of insecurity levels, then the probability of FI level (j) for a given household (i) can be specified as

$$P(Y_i > j) = P_{ij} = \frac{e^{(\alpha_j + X_i\beta)}}{1+e^{(\alpha_j + X_i\beta)}} \quad [3]$$

where β are the regression coefficients for X, α_j is the intercept for j logit.

The β values for all J insecurity levels are the same. However, this parallel lines assumption may very often not hold (Sasidharana & Menéndez, 2014).

Binomial logit model (BLM)

The BLM is a discrete choice model that has only two possible alternatives, 0 and 1, also called binary response model (Perez, 2012). The BLM parameters were estimated using the maximum likelihood estimation (MLE) technique. The binary logistic specification is suited to models where the endogenous variable is dichotomous. In this alternative modeling approach, the food security condition was measured using a one or zero, where zero represents food security (no FI and mild FI), and one represents FI (moderate FI and severe FI). The logistic distribution function represents a generalized form of the model for each dependent variable (Gujarati & Porter, 2009).

$$P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^Z}{1+e^Z}, \quad [4]$$

where $Z_i = \beta_1 + \beta_2 X_i$ and X_i are the logit model independent variables chosen for the regression.

As Z_i is within a range between $-\infty$ and $+\infty$, the probability of the households having the food security condition is somewhere between 0 and 1. As explained below (Eq. [5]) the logit model implies that the logarithm of the ratio is linearly related to X_i. Thus, when the logit result is positive, the value of the

regressor will be higher and the value of the regression is more likely to be closer to one (Gujarati & Porter, 2009).

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = B_1 + B_2 X_i + u_i \qquad [5]$$

The significance level of the models used in this study for acceptance and rejection of the null hypothesis is 0.01, 0.05 and 0.10, respectively. The STATA® 12.1 statistical package was used to conduct the logistic regression analysis.

Comparison of ordered logit and binomial logit models

The OLM and BLM were compared using Akaike's information criterion (AIC) and Bayesian information criterion (BIC). The AIC and BIC are two measures for evaluating the quality of the estimated statistical models. These are estimated by simultaneously considering the goodness of fit and complexity of the model. Both criteria use the log-likelihood (ln Lik), which is the log of maximum likelihood, also subtracting a term proportional to the number of parameters (k) in the model: ln Lik -αk, where α is equal to 2 for AIC and ln (N) for BIC (Posada & Noguera, 2007; Sasidharana & Menéndez, 2014).

Results

Descriptive analysis of the household

This research was conducted in indigenous communities of Sierra Tarahumara in the Mexican State of Chihuahua. It found that, on average, a household is made up of 4.28 members with an average age of 40 years. Of the heads of household, 65% are men, whereas 35% are women. In most households, the marital status is non-marital cohabitation (57.72%). The heads of household have a low level of education (23.58% are uneducated and 61.79% have primary education). With regard to the household economy, 34.15% are casual laborers, and the average income is 2199.92 Mexican pesos. Using the poverty line, we were able to calculate how many of the households in our survey were living in poverty in 2015. We found that 26% and 18.7% were living in poverty and extreme poverty, respectively. However, even if they were above the poverty line, there was at least one issue of social deprivation in 24.39% of households. Therefore, they also fall within the poverty category, since they are vulnerable due to social deprivation. Of the surveyed people, 21.95% do not own any land, whereas 54.47% have between one and two hectares. The main crop is maize, with an average production of 4.94 tons. Also, the households in

Table 3. Cronbach's alpha for households assessed using ELCSA

Average inter-item covariance:	0.14
Number of items in the scale:	15
Scale reliability coefficient:	0.96

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
Q1	0.19														
Q2	0.13	0.25													
Q3	0.10	0.08	0.14												
Q4	0.12	0.09	0.11	0.15											
Q5	0.12	0.17	0.10	0.10	0.23										
Q6	0.15	0.12	0.11	0.12	0.13	0.18									
Q7	0.14	0.16	0.09	0.10	0.12	0.14	0.22								
Q8	0.15	0.17	0.1	0.09	0.15	0.14	0.19	0.23							
Q9	0.12	0.10	0.12	0.12	0.1	0.11	0.10	0.10	0.17						
Q10	0.13	0.11	0.12	0.13	0.12	0.12	0.12	0.12	0.16	0.18					
Q11	0.14	0.16	0.08	0.10	0.15	0.13	0.15	0.17	0.13	0.13	0.24				
Q12	0.16	0.15	0.10	0.11	0.15	0.14	0.15	0.18	0.14	0.16	0.19	0.23			
Q13	0.14	0.16	0.09	0.10	0.14	0.13	0.19	0.19	0.13	0.14	0.20	0.20	0.24		
Q14	0.13	0.18	0.08	0.10	0.15	0.11	0.16	0.17	0.11	0.13	0.18	0.17	0.18	0.25	
Q15	0.13	0.17	0.08	0.10	0.14	0.12	0.16	0.18	0.12	0.13	0.21	0.18	0.22	0.20	0.25

Source: Computed from field data, 2015 (n=123)

these communities were found not to have access to an improved source of safe water, where 70.73% use well water and 29.27% use water from rivers and springs for cooking and drinking purposes. In terms of sanitation, only 30.89% of people use toilets as sanitation facilities, whereas 69.11% have to defecate in the open. Again, 82.11% are not connected to an electricity network, and 92.68% use firewood for cooking. Finally, we found that 66.67% are beneficiaries of the Prospera conditional cash transfer (Table 2).

Predictive models

This section evaluates the FI status of households in the indigenous communities of the Sierra Tarahumara and describes the results of the two predictive models developed in the study: OLM and the BLM.

ELCSA was analyzed at household level. The Cronbach's alpha coefficient was 0.96, which means that ELCSA consists of a set of highly correlated items with good internal reliability for the data (Table 3).

We found different FI categories among the households surveyed in the communities of the Sierra Tarahumara, as shown in Table 2. Considering the FI categories accounted for in the OLM, we found that 13.8% of the surveyed households had no FI, 10.6% had mild FI, 16.3% had moderate FI and 59.3% had severe FI. Considering the FI categories accounted for in the BLM, we found that approximately 75.6% of the surveyed respondents reported being food insecure and 24.4% claimed that they were food secure.

The results of the OLM and the BLM developed for the different FI levels are shown in Table 4. Table 4 shows the coefficients of the different predictors, the odds ratios, their associated standard errors and the cutoff thresholds. According to the OLM used in this study, five variables were important for explaining the food security

Table 4. OLM and BLM regression coefficient estimates

	OLM		**BLM**	
Dependent variable	**FI**		**FI**	
Independent variable	**Coefficient**	**Odds ratio**	**Coefficient**	**Odds ratio**
Income	-0.0004*** (0.0001)	0.9996 (0.0001)	-0.0007*** (0.0003)	0.9993 (0.0003)
Consumed seed stocks	1.6002*** (0.4901)	4.9540 (2.4280)	2.7821*** (1.1074)	16.1529 (17.8883)
Maize production	-0.1047*** (0.0272)	0.9006 (0.0245)	-0.1515*** (0.0438)	0.8594 (0.0376)
Casual employment	1.0714** (0.4680)	2.9193 (1.3663)	1.2642* (0.7105)	3.5401 (2.5152)
Age	-0.0284* (0.0155)	0.9720 (0.0151)	-0.0172 (0.0247)	0.9830 (0.0243)
Household size	0.1431 (0.1359)	1.1539 (0.1568)	0.0910 (0.2105)	1.0953 (0.2306)
Prospera	-0.2067 (0.4614)	0.8133 (0.3752)	0.2684 (0.7067)	1.3079 (0.9242)
Constant			2.6721 (1.5743)	14.4696 (22.779)
Cut1	-3.8705 (1.0913)		- -	- -
Cut2	-2.6215 (1.0331)		- -	- -
Cut3	-1.3857 (1.0069)		- -	- -
Likelihood ratio	-103.1992		-35.6409	
Brant test χ^2	8.16		-	
Correctly classified (%)			88.62	
Observations	123		123	

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are given in parentheses below the parameter estimates. FI: food insecurity, OLM: ordered logit model, BLM: binomial logit model. *Source*: Computed from 2015 field data.

condition of households. These were income of the head of household, consumed seed stocks, maize production, casual employment, and age of the head of household.

The OLM shows that the income of the head of household had a negative and significant relationship with household FI. The odds of being in the lower FI interval are 0.99 times *(p<0.01)* higher for households that have income, all other predictors being equal. The BLM also reveals that the income of the head of household had a negative and significant (p<0.01) relationship with household food security. If the other variables were unchanged, the odds ratio of being food secure increased by 0.99 when income increased by one Mexican peso (Table 4).

The OLM shows that the odds of suffering higher FI were 4.95 times (p<0.01) higher for households that consumed seed stocks, if the other predictors were unchanged. Likewise, the BLM demonstrates that the odds ratio of being food insecure increased by 16 times (p<0.01) when households consumed reserves of seeds for the next planting season (Table 4).

The two models showed that maize production had a significant and negative (p<0.01) relationship with household FI. The OLM revealed that the odds of having a lower FI level are 0.90 times (p<0.01) higher for households that produced maize. Similarly, the BLM showed that the odds ratio of being food insecure decreased by a factor of 0.86. This indicates that more food was available for consumption when there was a larger harvest, if the other variables were constant.

Furthermore, the OLM showed that the odds of suffering higher FI were 2.92 times (p<0.05) higher for households whose external income came from casual labor. Likewise, the BLM showed that the odds of suffering higher FI level were 3.5 times (p<0.1) higher for households who were in temporary employment, if the other variables were constant.

The age of the household head was statistically significant only in the OLM. The odds of having a lower FI level were 0.97 times (p<0.1) higher for households with elderly heads of household, if the other predictors were unchanged.

The Prospera variable was not significant in either of the two models proposed to measure FI.

The cut1, cut2, and cut3 values for the OLM in Table 4 are the threshold cutoff values that separate the different levels of FI. The thresholds indicate the predicted cumulative likelihoods when the independent variables are equal to zero. None of the confidence intervals for the three thresholds overlapped, showing that the four different food security levels were significantly different from one another. We used the Brant test to check the proportional odds assumption or the parallel regression assumption of the OLM. This test performs a series of Wald χ^2 tests to determine whether the coefficients differed across equations. The results show that χ^2 is 8.16, indicating that there is no violation of the proportional odds assumption across different FI levels. The BLM predicts 88.62% of the observations correctly (Table 4).

The OLM and BLM were compared using AIC and BIC selection criteria. These two measures evaluate the quality of the estimated statistical models. Figure 1 shows that the AIC (87.28) and BIC (109.78) values were lower for OLM than for BLM (AIC 226.40 and BIC 254.52) in this study. This shows that OLM outperformed BLM and can, consequently, be considered as a viable method for determining FI.

Discussion

We found that indigenous households were in a situation of poverty and extreme poverty, and many lack basic services. These results are comparable with those of CONEVAL (2016a) which reported that the minimum poverty line and food basket in February 2015 were 887.58 and 1,661.54 Mexican pesos, respectively. UN (2015) found that, worldwide, people living in rural areas and from poor and marginalized groups tend not to have access to an improved water source (about 16%) and sanitation facilities (about 50%) and are less likely to have piped water on the premises.

The internal consistency of ELCSA was good (Cronbach's α = 0.96). Similar results were reported by Muñoz *et al.* (2010) and Villagomez *et al.* (2014), where Cronbach's reliability coefficient was 0.95 and 0.93, respectively.

The value of this coefficient was well above the minimum recommended by the FAO (2012) (0.85). The FI categories described in our findings were comparable with results reported by Pérez-Escamilla *et al.* (2009), who studied a sample of 153 women with children aged from 1 to 5 years in Camp Perrin (South Haiti). Their findings suggested that 2% of the households

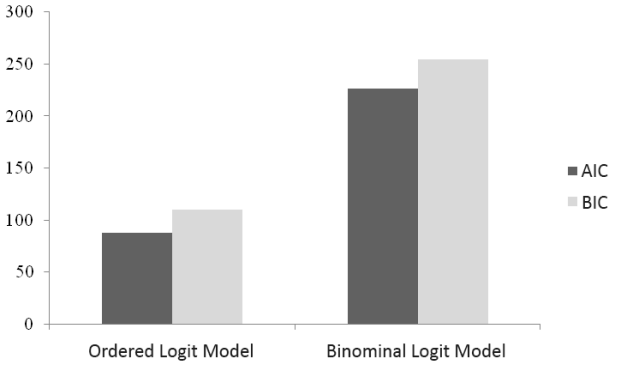

Figure 1. Comparison of ordered logit and binomial logit models. *Source*: Own calculations from regression results.

were food secure, 17% had mild FI, 25% had moderate FI and 57.3% had severe FI. Similarly, Melgar (2010) analyzed the results of the 2010 Municipal Census conducted by the National Statistics Institute (INE) in Guatemala, applying a version of ELCSA. The results showed that 8.1% of the households were food secure, 18.4% had mild FI, 16.7% had moderate FI and 46.8% had severe FI. However, Shamah-Levy *et al.* (2014) reported different results based on the analysis of the 2012 Mexican National Survey of Health and Nutrition (ENSANUT). They found that seven out of 10 households suffered some degree of FI (41.6% had mild FI, 17.7% had moderate FI and 10.5% had severe FI).

Like other authors, we found that income increases improve access to food, whereby households can afford healthier foods and better quality diets (Bauermann *et al.,* 2010; Bashir *et al*., 2012; Vieira *et al*., 2013). According to SHCP (2016), the minimum wage in Mexico was 70.10 Mexican pesos per day in 2015. This amounts to 2,103.00 Mexican pesos per month and contrasts with the results of this research, because most of the heads of households were located in the low- and medium-income tercile.

The main crop cultivated by the surveyed indigenous communities is maize. According to Generoso (2015), a dry cereal-based diet is less diversified, but remains the chief source of energy, proteins, vitamins and mineral salts for the poorest rural populations. In this respect, we can assume that the production of this crop in rural households is aimed mainly at self-consumption (FAO, 2013; CONEVAL, 2015).

We found that farmers consume their seed stocks. According to other authors, farmers in most developing countries use their own seeds saved from the previous year's harvest to meet the production needs for the next growing season. In times of food scarcity, however, farmers may be driven to consume their own seeds as a way of coping with hunger. This is an indication that the household is suffering from FI (FAO, 1999 2008; Cohen & Smale, 2012; GTZ, 2014). This may be because the scale of production does not meet household demand, which is a sign of the low productive capacity of households (CONEVAL, 2015).

Our study also found that the group of households whose householders are engaged in casual labor is food insecure. These findings are in contrast with Benson (2007) who studied poor neighborhoods in Bangladesh and found that households whose members have stable and well-paid employment were less prone to reduce food consumption.

Our results indicate that households headed by older people are more likely to be food insecure. Bashir *et al*. (2012) found that an increase by one year of age in rural households in the Punjab (Pakistan) decreases the chances of a household becoming food insecure by about 3%. Similar results were reported by Maitra & Prasada (2015) who studied poverty and food security based on a survey conducted among urban slum dwellers in Kolkata. They found that a larger share of working age adults in the household implies fewer dependants and, hence, a greater earning capacity for the household.

Our research found that Prospera has not managed to reach all poor households. Sonnino *et al*. (2014) and FAO/IFAD/WFP (2015) suggest that the primary reason is that the coverage of the social assistance programs is still limited. According to Neufeld (2007), this program has had a smaller impact than expected. We leave the analysis of possible measures for improving the impact of the Prospera program in the Sierra Tarahumara for future research.

Based on our results, we concluded that indigenous households do not have access to sufficient food, and therefore are living in a FI situation. It is recommended that the government should help households increase agricultural production, since rural families in a FI situation mainly depend on agriculture for their livelihoods. In addition, the government must provide access to basic services, which are deficient in the study of research. We believe that developing and fostering social policies that create work opportunities may be beneficial for food access, and eradicate the poor diets. Prospera does not seem to successfully lift people out of FI and poverty.

There are some limitations to this study. First, the sample size is relatively small and not necessarily representative of the entire Sierra Tarahumara, although the agro-socioeconomic holding structure is more or less in line with the region's demographics. A similar study with a larger number of participants should be conducted to consolidate our preliminary findings. Second, the econometric models applied to the survey results only provide an evaluation of positive or negative effect of the determinants of FI and do not provide a monetary evaluation. Despite these limitations, the main results of this analysis constitute an initial baseline and provide a better comprehension of the food situation of agricultural communities in the Sierra Tarahumara. These findings will help decision makers develop effective strategies for combating food insecurity. The developed methodology could be applied on a larger scale and in different regions. Future research should focus on conducting studies on food security, primarily in rural areas, paying special attention to local communities and indigenous people.

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